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REFERENCE BOOK
FOR
ASPHALT ROADBUILDERS

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THE BRITISH AMERICAN OIL
COMPANY LIMITED
Asphalt Department

REFERENCE BOOK

FOR

ASPHALT ROADBUILDERS

UNIVERSITY OF TORONTO
DEPARTMENT OF CIVIL ENGINEERING
Municipal and Structural

Published by

The Asphalt Department

THE BRITISH AMERICAN OIL COMPANY LIMITED

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FOREWORD

Asphalt, now so important to road-making, has a most romantic story.

In 4000 B.C., the Sumerians built homes of mud bricks bound with asphalt in Mesopotamia, which is now called Iraq. They also were in the habit of beating their copper instruments into shape on a base of bitumen.

In 700 B.C., King Nebuchadnezzar built a road in which he used a natural bitumen. He used asphalt to make waterproof the fabulous Hanging Gardens, built on the plain at Babylon to satisfy the whim of a homesick mountain princess. In his day, floors were made with stones or bricks, and bitumen.

In the British Museum, Nimrod's winged lions stand on a layer of ancient bitumen. It is believed that the basket of bulrushes in which the infant Moses was found by Pharoah's daughter was coated with the same material.

The hull of the "Santa Maria", which brought Christopher Columbus to America, was painted with liquid asphalt to make it stronger.

The ancient Persians used asphalt when making statues of their gods. Even today, after 4,500 years, the statues are in a good state of preservation.

When the Greek philosopher and physician, Hippocrates, was alive asphalt was used in medicine.

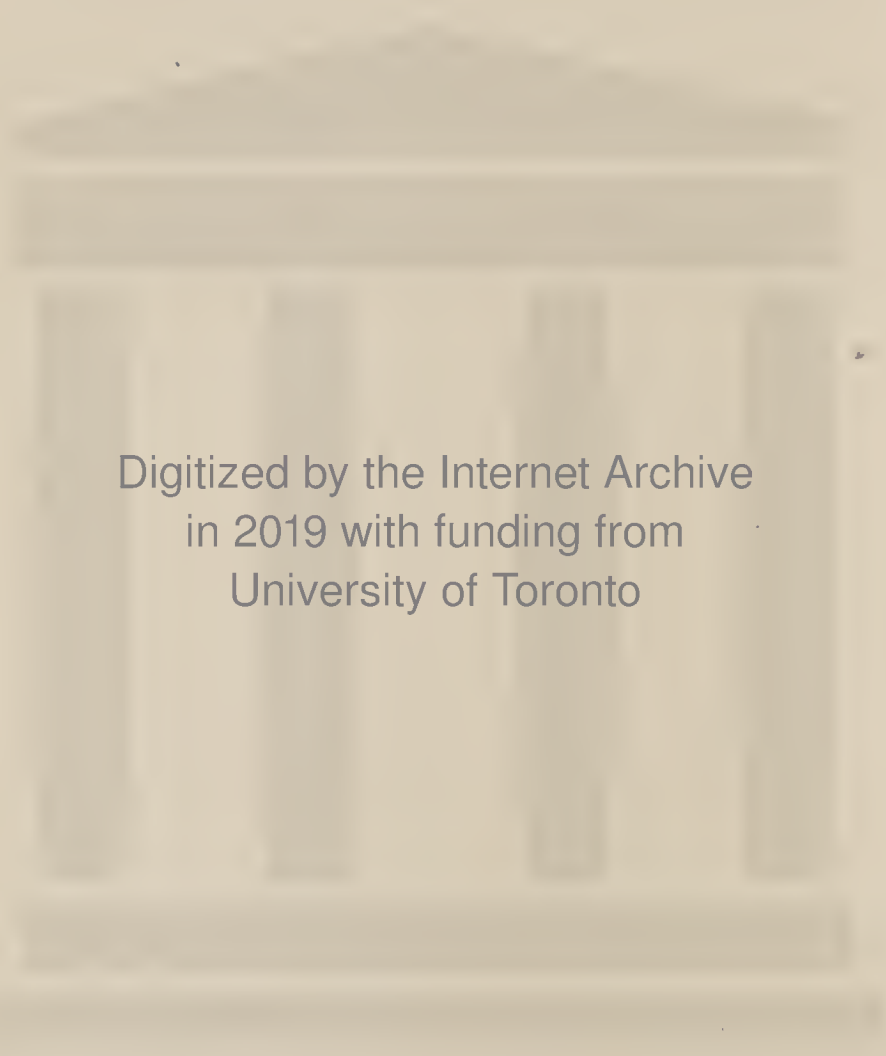
Asphalt has played its part in war, and has changed the course of history, too.

The Assyrians used burning bitumen as a war weapon. This was developed into the famous "Greek Fire", which became the most powerful military weapon of a later age.

An improved form of "Greek Fire", the making of which was a closely-guarded secret, was the chief reason why Constantinople, or Byzantium, remained impregnable for over a thousand years (330 A.D. to 1453 A.D.).

It is thought that, without the preservation of Greek culture in Byzantium, the Renaissance would not have been possible, and the modern world could not have come into existence.

Today, asphalt is playing an ever-increasing role. Asphalt road-making on a large scale is a modern development, and in this field Canada is to the fore.



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The growth in recent years of the use of asphalt for roads in Canada has made available a vast body of data on its employment.

The purpose of this little book has been to concentrate in one handy, pocket-size volume as much of this information as possible.

No attempt has been made to originate. Controversial material has as far as possible, been avoided. In every case the best available authorities have been quoted.

The British American Oil Company Limited hopes that road engineers, contractors and road authorities will find the book useful, not as a substitute for existing basic works on asphalt but as a handy reference book, on the job.

The chapter headings suggest the scope of the work:—

'Bituminous Materials'—summarizes, with a glossary, the usually accepted asphaltic materials, their uses and definitions.

'Provincial Paving Specifications'—makes available to engineers in one Province detailed information as to the practice in other Provinces.

Tables and Charts—speak for themselves. Every effort has been made to include those tables and charts most likely to be needed most often in actual road construction.

Minerals and Mineral Aggregate—Again makes available in condensed form commonly accepted definitions and practices.

Soils—which includes a glossary of terms and an outline of soil classification, as prescribed by the Bureau of Public Roads in the U.S.A., should be useful these days when roads are built from the foundations up rather than from the top down.

Much of the work involved in the compilation of data and the spraying and quantity charts, etc., has been the effort of Mr. J. A. Clark, B.Sc., formerly with the Milton Hersey Company Limited, Montreal, the Department of Highways of the Province of New Brunswick and the Asphalt Division of The British American Oil Company Limited.

Grateful acknowledgement is also due to Provincial Highway Departments across Canada who have not only cooperated in supplying specifications but also in revising and approving the form in which they appear in this little book.

ASPHALT DEPARTMENT

THE BRITISH AMERICAN OIL CO., LTD.

CHAPTER 1

BITUMINOUS MATERIALS

(a) GLOSSARY OF BITUMINOUS MATERIALS

ASPHALT: A black or dark brown solid or semi-solid bonding material, composed of hydrocarbons which become softer on heating and gradually liquefy. The predominating constituents are bitumens which naturally occur as solids or very viscous liquids, or which may be constituents of crude petroleum. When occurring as a solid or semi-solid in nature, the bitumens are generally accompanied by varying amounts of mineral matter. The bitumens are distinguished by their complete solubility in carbon disulphide.

ASPHALT CEMENT: An asphalt suitable for direct use in the manufacture of bituminous pavements. It includes products which are prepared for use by fluxing with other grades of asphalt. The finished asphalt has a penetration between 5 and 250 when tested under an applied load of 100 grams for 5 seconds at a temperature of 77°F.

PAVING ASPHALT: An asphalt suitable for use in the construction of sheet asphalt, asphaltic concrete, joint filler, asphaltic macadam, or asphaltic block pavements.

ROCK ASPHALT: A naturally occurring sandstone or limestone impregnated with asphalt.

LIQUID ASPHALT: A trade term only.

NATIVE ASPHALT: An asphalt suitable for use with little or no processing occurring as such in nature (i.e. Trinidad Lake Asphalt).

BITUMENS: A general term applied to mixtures of hydrocarbons or material of pyrogeneous origin, or combinations of these types. The hardness and boiling range may vary and the latitude include gaseous to solid derivatives. Bitumens are fusible and characterized by their complete solubility in carbon disulphide.

The A.S.T.M. classify Bituminous Materials as follows:

(1) **LIQUID BITUMINOUS MATERIALS:** Those having a penetration at 77°F. under a 50 gram load for one second of over 350.

(2) **SEMI-SOLID BITUMINOUS MATERIALS:** Those having a penetration at 77°F under a 100 gram load for five seconds of more than 10 and under a load of 50 grams for one second of not over 350.

(3) **SOLID BITUMINOUS MATERIALS:** Those having a penetration at 77°F. under a load of 100 grams applied for 5 seconds of not more than 10.

ASPHALTENES: The components of bitumen in petroleum or products derived from petroleum, asphalt cements or native bitumens which are soluble in carbon disulphide but insoluble in low boiling range petroleum naphtha (the naphtha used in the test is 86° A.P.I. naphtha composed principally of straight-chain paraffin hydrocarbons).

CARBENES: The components of bitumen in petroleum or products derived from petroleum, asphalt cements or native bitumens which are soluble in carbon disulphide but insoluble in carbon tetrachloride. From the above it may be observed that asphaltenes are high-molecular weight constituents of bitumen and carbenes, if present, are the highest molecular weight portion of the asphaltenes.

CUT-BACK ASPHALTS: Asphalts which have been liquefied or plasticized by the addition of petroleum distillates.

EMULSIFIED ASPHALTS: A liquid mixture of very small particles of bitumen suspended in water or aqueous solution. Emulsions are often produced by mixtures of soaps or some forms of mineral matter.

FLUXES OR FLUXOIL: Bituminous materials, generally liquid, in which the predominant constituent is bitumen, used for the purpose of changing a harder asphalt to a softer grade.

PETROLEUM: A liquid bitumen occurring as such in nature (i.e. crude oil).

PYROBITUMEN: A broad term applied to comparatively non-volatile naturally occurring bodies, composed principally of hydrocarbons of high molecular weight associated with mineral matter. The non-mineral portion is sparingly soluble in carbon disulphide. Asphaltic pyrobitumens include albertite, elaterite, wurlitzite and impsonite, while non-asphaltic pyrobitumens are peat, lignite, bituminous coal, and their respective shales.

(b) EXPLANATION AND SIGNIFICANCE OF TERMS RELATED TO TESTS ON BITUMINOUS MATERIALS.

CONSISTENCY: In the use and standardization of bituminous materials for various types of paving mixtures and treatment of highway surfaces with asphaltic materials, the control of consistency is of primary importance. The control tests are as follows:

PENETRATION: The consistency of a bituminous material expressed as the distance in hundredths of a centimeter that a standard needle vertically penetrates a sample of the material under standard conditions of loading, 100 grams; temperature, 77°F.; and time, 5 seconds, (A.S.T.M. D-5-25). The penetration of the asphalt cement to be used in a paving mixture depends upon many variables such as the climate, the nature of the traffic, the grading of the aggregate, the amount of voids, the amount of compression obtainable, the ductility and cementing strength of the asphaltic cement, and the amount of the dust filler.

FLOAT TEST: The consistency of a bituminous material expressed as the time in seconds required to loosen a standard plug of the material under fixed conditions (A.S.T.M. D-139-27). This test is used for materials of a limited range of consistency between liquid asphalts and asphalt cements.

VISCOSITY: The measure of the resistance to flow of a bituminous material, usually stated as the time in seconds of flow for a given amount through a standard orifice at a specified temperature. The test is used as a control for liquid asphalts in road construction and is of value in determining the adaptibility of the bituminous material for a given purpose such as priming, road mixing, surface treating, etc. Saybolt Furol Viscosities (A.S.T.M. D-88-38) are generally determined at 122°F., but for materials of exceptional low viscosities the control temperature may be reduced to 77°F. For accuracy and convenience with materials of higher viscosities not feasibly tested at 122°F.; control temperatures of 140°F., 180°F. or 210°F. are recommended as standards.

DUCTILITY: Indicates the capacity of the bituminous material to elongate or stretch. The ductility is measured by the distance to which two ends of a briquette of asphaltic material will elongate before breaking when pulled apart at a specified speed of 5 cm. per minute and at a specified temperature of 77°F. (25°C.). This test is useful in the identification of bituminous materials; gauging uniformity of products and their adaptability with regard to certain uses. It will often differentiate blown petroleum asphalts from residual asphalts. It is a measure of the property of the material to expand and contract without breaking, as well as a measure of the cementing value (A.S.T.M. D-113-35). Ductilities are also measured based on a specified speed of 1 cm. per minute and a specified temperature just above freezing point (39°F. to 40°F.). Where the bituminous material is subjected to considerable variation in temperature it is important that it should have satisfactory ductility within the range of temperature change to which it will be subjected.

FIXED CARBON: Is to some extent a measure of the chemical constitution and a factor in the determination of the source and uniformity of an asphalt. Fixed carbon is not free carbon, but includes free carbon which is ordinarily absent in asphaltic cements.

FLASH POINT: This is a measure of the amount of volatile hydrocarbons that are present in the bituminous material and its readiness to volatilize by heat. It is the temperature read on the thermometer at the time of the flame application which causes a distinct flash in the interior of the test cup. The flash point primarily is used to determine the adaptiblity of bituminous substances for certain definite uses. It serves as a criterion of the fire hazard. It should be at least 50°F. higher than the maximum temperature to which the material is to be subjected in practical operations. There are several standard methods in use such as Pensky-Martens, (A.S.T.M. D-93-36); Cleveland Open Cup, (A.S.T.M. D-92-33); Tagliabue Closed Tester, (A.S.T.M. D-56-36); and Tagliabue Open Tester.

IMPURITIES: A measure of the care with which asphaltic cement has been refined and handled. In large quantities, impurities indicate a poor grade of asphalt. Water as an impurity acts as a diluent and would cause foaming on heating. Ash or mineral matter is not considered an impurity if it is a natural constituent of the asphaltic cement but, in paving work the mix and cementing value must be figured on bitumen alone.

SOFTENING POINT or MELTING POINT: The transition temperature at which fusible bituminous substances pass from the solid to the liquid state. This transition is often slow because of the composite character of the substance present. It is a valuable test and is used for purposes of identification, and as a control test for materials fusing at high temperatures. By means of it one can determine the adaptibility of a bituminous material for certain definite uses, including its resistance to atmospheric or artificial heat. There are various methods of carrying out this test, one being the standard "Ring and Ball" Method (A.S.T.M. D-36-26). The melting point desired depends upon the mixture in which it is to be used. If the amount of fine dust in the mineral aggregate is low, the asphalt should have a melting point higher than the highest temperature to which the pavement is subjected. It has been found practical to use asphalts of lower melting points, depending on aggregate gradings and the amount of asphalt in the mixture.

SOLUBILITY IN CARBON DISULPHIDE: This is a measure of the purity of an asphaltic material. Any carbonaceous material such as coal tar or pitch is detected by this carbon disulphide solubility test.

SOLUBILITY IN CARBON TETRACHLORIDE: This is nearly the same as the solubility in carbon disulphide. It is claimed that an asphalt having more than 1½% difference in solubility in carbon disulphide and carbon tetrachloride has been subjected to excessive heat in refining (A.S.T.M. D-165-27). Modern refining equipment tends to produce asphalts which have nearly the same solubility in carbon disulphide as in carbon tetrachloride.

SPECIFIC GRAVITY: The specific gravity of bituminous material is the ratio of the weight in air of a given volume of the material at a stated temperature to the weight in air of an equal volume of distilled water at the stated temperature. The value of this test lies in identifying bituminous materials, controlling uniformity of supply, determining the weight of a given volume, calculating the volume of the bituminous binder in the paving mixture, etc. For asphalt cement the specific gravity is generally greater than 1.000. When more than 1.000, there will be less tendency for water to float out of the asphaltic mineral matter. Paraffin base oil and air-blown products may have a specific gravity less than 1.000 (A.S.T.M. D-70-27).

SUSCEPTIBILITY FACTOR: Many test methods have been developed to indicate the effect of temperature change upon asphalt. A penetration relationship may be expressed in one figure. In Canada this is called the susceptibility factor or ratio and is obtained as follows:

$$\text{Factor} = \frac{\text{Penetration @ 100°F., 100 grams, 5 seconds.}}{\text{Penetration @ 77°F., 100 grams, 5 seconds.}}$$

(c) BITUMINOUS MATERIALS AND GENERAL SPECIFICATIONS COVERING SAME.

Bituminous materials used in highway construction and road surface treatments are generally referred to as belonging to the following groups:

(1) **ASPHALT CEMENTS.**
(2) **SLOW CURING LIQUID ASPHALT MATERIALS. (SC).**
(3) **MEDIUM CURING LIQUID ASPHALT MATERIALS. (MC).**
(4) **RAPID CURING LIQUID ASPHALT MATERIALS. (RC).**

Each of these groups consists of several grades of that particular type of material.

(1) **ASPHALT CEMENTS** are oil asphalts or mixtures of refined liquid asphalt and refined solid asphalt, prepared from a crude asphaltic petroleum. These asphaltic cements are of a semi-solid consistency and both aggregate and asphaltic cement must be heated to a high temperature to produce a satisfactory mixture.

(2) **SLOW CURING TYPE LIQUID ASPHALTIC MATERIALS** are obtained as residues from certain carefully controlled refinery operations. These harden very slowly when used as a binder for a road surface, since the gasolene, kerosene and other distillate fractions have been removed in their preparation. This material consists of petroleum residual asphalt being a combination of oils of high boiling range and the residual asphalt in the crude oil.

(3) **MEDIUM CURING TYPE LIQUID ASPHALTIC MATERIALS** are made by liquifying medium soft grade asphalt cements with a kerosene type solvent. This solvent evaporates comparatively more slowly than that used in the Rapid Curing types. The Medium Curing types are used more as binders for dense graded aggregates.

(4) **RAPID CURING TYPE LIQUID ASPHALTIC MATERIALS** are made by liquifying comparatively hard asphalt cements with a gasolene type solvent. This gives a quick setting binder which is desirable for use with open graded aggregates and for surface treatments.

GENERAL SPECIFICATIONS OF BITUMINOUS MATERIALS: Throughout Canada, different Highway Departments and Cities have set up specifications of their own for particular grades of bituminous material. This is the result of efforts to secure specific types which will give the best results with local construction methods, climatic conditions and the mineral aggregate available. Therefore, it is difficult to draw up one set of specifications which will fully agree with all ideas on different types. A generalization has been attempted in the following tables which show the specifications as set down by The Asphalt Institute, the Federal Government and the Ontario Department of Highways.

ASPHALT CEMENTS

	Federal 150-180 Pen		D.H.O. 120-140 Pen		D.H.O. 71-80 Pen		D.H.O. 61-70 Pen		City of Toronto 51-60 Pen		D.H.O. Crack Filler			
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water %				0		0		0		0		0		
Flash Point (O.C.) °F.	450		500		500		500		347		500			
Softening Point (B&R) °F.	100	115	109		120		127				140	150		
Penetration at 77°F., 100 grs. 5 sec.	150	180	120	140	71	80	61	70	50	60	40	60		
Volatility 325°F., 50 grs. 6 hours % loss wt.		1.0		1.0		1.0		1.0		2.0		1.0		
Loss in Penetration after Volatility %		60		25		25		25		60		25		
Ductility at 77°F.	80				35		35		50		10			
Susceptibility Factor						3.2		2.8		2.8		2.8		
Solubility in CS_2, %	99.5		99.5		99.5		99.5				99.5			
Solubility in CCl_4, %									99.0					
Working Temperature °F.			300	350	250	300	250	325			300	350		
Use Recommended by Department Specifying	Plant-Mix hot.		Penetration. Hot Bituminous Mixture.		Hot-Mix, average traffic.		Hot-Mix, heavy traffic.		Hot-Mix, Binder Course and Sheet Asphalt.		Pouring cracks and joints. Waterproofing walls, piers, etc.			

SC TYPES — GRAVEL DUST LAYER and SLOW CURING LIQUID ASPHALTIC MATERIALS

	Federal Gravel Dust Layer		D.H.O. Gravel Dust Layer						Asphalt Inst. SC-0		Federal SC-25		D.H.O. SC-1		Asphalt Inst. SC-1		Federal SC-100†		Alberta SC-2	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water, %										0.5						0.5				0.5
Flash Point (O.C.) °F.	150		150						150		150		150		150		150		200	
Viscosity—Saybolt Furol																				
At 77°F.	30	60							75	150										
At 122°F.											25	60	30	60	75	150	100	200	100	200
At 140°F.																				
At 180°F.																				
Viscosity—S.U. At 130°F.			95	115																
Softening Point (B&R) °F.																				
Initial Boiling Point °F.	400		475																	
Distillation % By Volume Off																				
At 437°F.																				
At 560°F.				10																
At 600°F.				20																
At 680°F.		50							15	40		40		35	10	30		30		20
Asphalt Residue of 100 Penetration									40						50					
Ductility at 77°F. (on Res.)									100		100		100		100		100		100	
Distillation Residue % by weight																			80	
Float Test at 122°F., secs. (on Res.)									15	100					20	100				
Solubility in CS_2, %	99.5		99.5								99.5		99.5				99.5		99.5	
Solubility in CCl_4, %									99.5*						99.5*					
Working Temperature °F. (Guidance only)	Atmospheric		Atmospheric										Atmospheric							
Use Recommended by Department Specifying.	Dust Layer.		Dust laying on traffic-bound roads.						Dust Layer.		Dust laying. Light Blotter Treatment or Road Oiling.		Heavy Dust Layer.		Dust Layer.		Blotter Treatment.			

*Under Asphalt Institute Specifications if the material fails to meet the requirement for solubility it will be acceptable if its solubility in Carbon Disulphide is 99% plus, and the proportion of Bitumen soluble in Carbon Tetrachloride is 99.65% plus.

†Under Federal Spec., the designation used in reference to a type is in all cases the approximate minimum S.F. Viscosity of that type as determined at 122°F.

(Continued) SC TYPES — SLOW CURING LIQUID ASPHALTIC MATERIALS

	Asphalt Institute SC-2		Federal SC-200		Alberta SC-3		Asphalt Institute SC-3		Asphalt Institute SC-4		Federal SC-400		Alberta SC-4		Asphalt Institute SC-5		Federal SC-2000		D.H.O. SC-5	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water %		0.0				0.5		0.0		0.0				0.5		0.0				
Flash Point (O.C.) °F.	175		200		200		200		225		200		200		250		225		300	
Viscosity—Saybolt Furol																				
At 77°F.																				
At 122°F.			200	300	200	300					400	800	400	500						
At 140°F.	100	200					250	500												
At 180°F.									125	250					300	600				
Viscosity—S.U. At 130°F.																				
Softening Point (B&R) °F.																	70	90	70	90
Initial Boiling Point °F.																				
Distillation % By Volume Off																				
At 437°F.																				
At 560°F.																				
At 600°F.																				
At 680°F.	5	25		25		20	2	15		10		20		15		5		7.5		7.5
Asphalt Residue of 100 Penetration	60						70		75						80					
Ductility a 77°F., (on Res.)	100		100		100		100		100		100		100		100		100		100	
Distillation Residue					80								90							
Float Test at 122°F., sec. (on Res.)	25	100					50	125	60	150					75	200				
Solubility in CS_2, %			99.5		99.5						99.5		99.5				99.5		99.5	
Solubility in CCl_4, %	99.5*						99.5*		99.5*						99.5*					
Working Temperature °F. (Guidance only)																			150	225
Use Recommended by Department Specifying.	Blotter Treatment. Mulch Treatment. Road-Mix with dense graded aggregates.		Blotter Treatment.				Road-Mix, with dense graded aggregates.		Cold-laid, Plant-Mix, dense graded aggregates.		Pre-Mix, cold-laid with dense graded aggregates.		Used in Blotter Treatment with aggregate containing considerable soil fines.		Cold-laid, Plant-Mix, dense graded aggregates.		Pre-Mix, cold-laid with dense and open graded aggregates.		Hot or warm Plant-Mix with graded aggregates.	

*Under Asphalt Institute Specifications if the material fails to meet the requirement for solubility it will be acceptable if its solubility in carbon disulphide is 99% plus, and the proportion of Bitumen soluble in carbon tetrachloride is 99.65% plus.

MC TYPES — MEDIUM CURING LIQUID ASPHALTIC MATERIALS

	Asphalt Inst. MC-0		Federal MC-15		D.H.O. MC-1		Asphalt Inst. MC-1		Federal MC-75		D.H.O. MC-2		Asphalt Inst. MC-2		Federal MC-200		D.H.O. MC-3	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water, %		0.0						0.0						0.0				
Flash Point (O.C.) °F.	100		80		80		100		80		80		150		80		80	
Viscosity—Saybolt Furol																		
At 77°F.	75	150	30	200														
At 122°F.					15	25	75	150	75	200	100	200			200	300	200	300
At 140°F.													100	200				
Distillation % By Volume Off																		
At 374°F.						12					3							
At 437°F.		25*	12		16			20*	4		7			10*	3		4	
At 500°F.	40	70	16		20		25	65	8		12		15	55	7		8	
At 600°F.	75	93					70	90					60	87				
At 680°F.				50		50				35		30				30		27
Distillation Residue % by Volume Diff.	50						60						67					
Softening Point (B&R) °F. (on Res.)																		
Penetration at 77°F., 100 gr. 5 sec. (on Res.)	120	300	100	250	70	300	120	300	100	250†	100	200	120	300	100	250	100	200
Ductility at 77°F. (on Res.)	100‡		100		100		100‡		100†		100		100‡		100		100	
Solubility in CS_2, %			99.5		99.5				99.5		99.5				99.5		99.5	
Solubility in CCl_4, %	99.5						99.5						99.5					
Application Temp. °F. (Guidance only).					70	100					115	150					135	160
Use Recommended by Department Specifying.	Priming tightly bonded surfaces.		Priming, Road oiling or light blotter treatments. Bituminous stabilization, dense, gravel, sand, clay mixtures.		Base Priming.		Priming loosely bonded, fine grained surfaces.		Blotter treatments. Road-Mix, dense graded, open graded or macadam aggregates. Pre-Mix, cold-laid, dense or open graded aggregates. Bituminous stabilization (dense, clay-silt soils).		Road-Mix Retread. Cold, Pre-Mix gravel mulches. Soil stabilization (dense, clay-silt soils).		Priming loosely bonded, coarse grained surfaces. Seal and Carpet Coats, graded cover. Gravel Mulch. Road-Mix or Cold Patch, dense graded aggregates.		Blotter treatments. Road-Mix, open graded or macadam aggregates. Pre-Mix, cold laid, dense or open or macadam aggregates. Seal Coating. Bituminous stabilization.		Cold, Pre-Mix Retread. Road-Mix Retread (mid-summer conditions). Cold, Pre-Mix open graded gravels.	

*Under Asphalt Institute Specifications for Distillation Range, figures represent percentage of total distillate to 680°F.

†Under Federal Spec., when MC-75 and MC-400 are used for certain types of "mixed-in-place" construction or, road or plant mix, using dense graded aggregates, the requirements for maximum penetration on the distillation may be waived. If the residue is too soft for a ductility test at 77°F. it will be acceptable if its ductility at 60°F. is 100 plus.

‡Under Asphalt Institute Spec., if penetration of residue is more than 200 and its ductility at 77°F. is less than 100, the material will be acceptable if the ductility at 60°F. is 100 plus.

(Continued) MC TYPES MEDIUM CURING LIQUID ASPHALTIC MATERIALS

	Asphalt Inst. MC-3		Federal MC-400		D.H.O. MC-4		Asphalt Inst. MC-4		Federal MC-1000		D.H.O. MC-5		Asphalt Inst. MC-5			D.H.O. M.I.P.	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water, %		0.0						0.0						0.0				
Flash Point (O.C.) °F.	150		80		80		150		80		80		150				80	
Viscosity—Saybolt Furol																		
At 122°F.			400	800	400	600					1000	1400					100	150
At 140°F.	250	500																
At 180°F.							125	250	100	300			300	600				
Distillation % By Volume Off																		
At 374°F.																	2	
At 437°F.		5*			1			0*						0*			4	
At 500°F.	5	40	3		5			30	2		4			20			8	
At 600°F.	55	85					40	80					20	75				
At 680°F.				27		25				25		22						20
Distillation Residue % by Volume Diff.	73						78						82					
Softening Point (B&R) °F. (on Res.)																	60	
Penetration at 77°F., 100 gr., 5 sec. (on Res.)	120	300	100	250†	100	200	120	300	100	250	100	200	120	300				
Ductility at 77°F. (on res.)	100‡		100†		100		100‡		100		100		100‡					
Solubility in CS_2, %			99.5		99.5				99.5		99.5						99.5	
Solubility in CCl_4, %	99.5						99.5						99.5					
Application Temp. °F. (Guidance only)					150	190					175	225					100	150
Use Recommended by Department Specifying.	Seal and Carpet Coats, coarse sand or graded gravel cover. Road-Mix or Cold Laid, open graded aggregates. Cold Laid, Plant-Mix, dense graded aggregates with high % passing 200 mesh.		Blotter treatments. Pre-Mix, Cold Laid, dense, or open, or macadam aggregates. Bituminous stabilization, open, sandy soils.		Warm Pre-Mix Retread. Warm Pre-Mix open graded gravels.		Seal and Carpet Coats, clean ¾" aggregate cover. Road-Mix, open graded aggregate, max. dia. 1", high % passing 10 mesh. Cold Laid Plant-Mix, dense graded aggregates.		Pre-Mix, Cold Laid, open graded or macadam aggregates. Bituminous stabilization, open, sandy soils.		Hot Pre-Mix Retread. Hot Pre-Mix, open graded gravels.		Seal and Carpet Coats, clean ¾" aggregate cover. Cold Laid Plant Mix, dense graded aggregate, max. dia. 1", med. % passing 200 mesh.				Cold, Road-Mix gravel mulches. Cold, Pre-Mix, dense graded aggregates.	

*Under Asphalt Institute Specifications for Distillation Range, figures represent percentage of total distillate to 680°F.

†Under Federal Spec., when MC-75 and MC-400 are used for certain types of "mixed-in-place" construction or, road or plant mix, using dense graded aggregates, the requirements for maximum penetration on the distillation may be waived. If the residue is too soft for a ductility test at 77°F. it will be acceptable if its ductility at 60°F. is 100 plus.

‡Under Asphalt Institute Spec., if penetration of residue is more than 200 and its ductility at 77°F. is less than 100, the material will be acceptable if the ductility at 60°F. is 100 plus.

RC TYPES — RAPID CURING LIQUID ASPHALTIC MATERIALS

	Asphalt Inst. RC-0		Federal RC-60†		D.H.O. RC-1		Asphalt Inst. RC-1		Federal RC-100†		D.H.O. RC-2		Asphalt Inst. RC-2		Federal RC-200†		D.H.O. RC-3	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water %		0.0						0.0						0.0				
Flash Point (O.C.) °F.			80		80				80		80		80		80		80	
Viscosity—Saybolt Furol																		
At 77°F.	75	150																
At 122°F.			60	70	60	70	75	150	100	200	100	200			200	300	200	300
At 140°F.													100	200				
At 180°F.																		
At 212°F.																		
Distillation % By Volume Off																		
At 374°F.	15*		6		6		10*		5		6				3		10	
At 437°F.	55		14		14		50		10		10		40*		7		15	
At 500°F.	75		18		18		70		14		14		65		10		18	
At 600°F.	90						88						87					
At 680°F.				40		35				35		32				35		30
Distillation Residue % by Volume Difference.	50						60						67					
Softening Point (B&R) °F. (on Res.)																		
Penetration at 77°F., 100 grs. 5 sec. (on Res.)	80	120	60	160	60	160	80	120	60	160	60	160	80	120	60	160	60	160
Ductility at 77°F., (on Res.)	100		100		80		100		100		80		100		100		80	
Solubility in CS_2, %			99.5		99.5				99.5		99.5				99.5		99.5	
Solubility in CCl_4, %	99.5						99.5						99.5					
Application Temperature °F (Guidance only).					75	125					125	150					135	160
Use Recommended by Department Specifying.	Seal and Carpet Coats with or without light sand cover.		Blotter treatments.		Priming and Mulching in base preparation.		Seal and Carpet Coats with coarse sand cover. Road Mix, open graded sand aggregates.		Pre-Mix, Cold Laid, open graded aggregates. Surface Treatment. Bituminous stabilization with open sandy soils.		Surface Treatment (cold weather) Sand soil stabilization.		Surface Treatment ¼" cover. Road-Mix, open graded sand and macadam aggregates. Cold Patch, open graded aggregates. Cold-Laid, Plant-Mix sand.		Pre-Mix, Cold Laid, open graded or macadam aggregates. Surface Treatment. Bituminous stabilization, open sandy soils.		Surface Treatment (general purpose). Pre-Mix Retread (rapid setting conditions).	

*Under Asphalt Institute Specifications for Distillation Range, figures represent percentage of total distillate to 680°F. This method adopted Dec. 13, 1939.
†Under Federal Specifications designation used in reference to a type is in all cases the approximate minimum S.F. Viscosity of that type as determined at 122°F.

(Continued) RC TYPES — RAPID CURING LIQUID ASPHALTIC MATERIALS

	Asphalt Inst. RC-3		Federal RC-400†		D.H.O. RC-4		Asphalt Inst. RC-4		Federal RC-1000†		D.H.O. RC-5		Asphalt Inst. RC-5					
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Water, %		0.0						0.0						0.0				
Flash Point (O.C.) °F.	80		80		80		80		80		80		80					
Viscosity—Saybolt Furol																		
At 77°F.																		
At 122°F.			400	800	400	600												
At 140°F.	250	500																
At 180°F.							125	250	100	300			300	600				
At 212°F.											50	90						
Distillation % By Volume Off																		
At 374°F.			2		8						5							
At 437°F.	25*		4		13		8*		1		8							
At 500°F.	55		7		16		40		3		10		25*					
At 600°F.	83						80						70					
At 680°F.				30		25				25		23						
Distillation Residue % by Volume Difference	73						78						82					
Softening Point (B&R) °F. (on Res.)																		
Penetration at 77°F. 100 grs. 5 sec. (on Res.)	80	120	60	160	60	160	80	120	60	160	60	160	80	120				
Ductility at 77°F. (on Res.)	100		100		80		100		100		80		100					
Solubility in CS_2, %			99.5		99.5				99.5		99.5							
Solubility in CC_4, %	99.5						99.5						99.5					
Application Temperature °F. (Guidance only).					150	190					175	225						
Use Recommended by Department Specifying.	Surface Treatment, 3/8" —5/8" cover. Road-Mix, macadam aggregates. Cold-Laid, Plant-Mix, open graded aggregates.		Pre-Mix, Cold-Laid, open graded or macadam aggregates. Surface Treatment. Penetration macadam. Bituminous stabilization, open sandy soils.		Surface Treatment (heavy traffic). Warm, Pre-Mix Retread (rapid setting conditions).		Surface Treatment, 5/8" cover. Cold-Laid, Plant-Mix, macadam aggregates.		Surface Treatment. Pre-Mix, Cold-Laid, macadam or open graded aggregates. Penetration macadam.		Surface Treatment (heaviest traffic). Hot, Pre-Mix Retread (rapid setting).		Surface Treatment, 3/4" cover. Cold-Laid, Plant-Mix, macadam aggregates. Penetration Macadam (cold weather).					

*Under Asphalt Institute Specifications for Distillation Range, figures represent percentage of total distillate to 680°F. This method adopted Dec. 13, 1939.
†Under Federal Specifications, the designation used in reference to a type is in all cases the approximate minimum S.F. Viscosity of that type as determined at 122°F.

(d) GLOSSARY OF TERMS RELATIVE TO BITUMINOUS SURFACES (AS GENERALLY ACCEPTED):

ASPHALTIC CONCRETE: A mixture of asphalt cement and mineral aggregate. The mineral aggregate consists of broken stone, broken slag or crushed gravel with sand and mineral filler.

BINDER COURSE: An intermediate course between a base course (i.e. concrete, water-bound macadam) and a surface course (i. e. sheet asphalt). Usually a coarse graded aggregate seldom containing mineral filler.

BLOTTER TREATMENT OR INVERTED PENETRATION The treated roadbed or surface is sprayed with a relatively slow curing liquid asphaltic material and covered with mineral aggregate. Compaction by traffic forces the mineral aggregate to blot up the bitumen which is interspersed and binds the particles.

BITUMINOUS CARPET COAT: A mat of bituminous cemented mineral aggregate resulting from the surface treatment of a road or surface with bituminous material and mineral aggregate cover.

BITUMINOUS MULCH: A paving mixture (road or plant mix) made with a mineral aggregate with coarse and fine fractions in a more balanced proportion than is found with retread.

BITUMINOUS RETREAD: A paving mixture (road or plant mix) made with a mineral aggregate of open grading characteristic, having comparatively little material passing the 4 mesh.

PENETRATION MACADAM: A type of pavement construction in which a broken stone aggregate of relatively coarse and uniform fragments is first spread and inter-locked by compaction. Hot asphalt cement applied to the surface, penetrates the layer of stone before it cools, coating and binding the fragments. Proper sized key stone is rolled in, filling the surface voids. A final surface treatment seals the pavement.

PLANT-MIX SURFACE SEAL: A mixture of bituminous and mineral aggregate passing 4 mesh.

PRIME COAT: An application of low viscosity liquid asphaltic material to a road surface, preparatory to the construction of some types of surface course, i.e. mulch, retread, asphaltic concrete, etc.

SHEET ASPHALT: A mixture of asphalt cement with graded sand passing the 10 mesh sieve and mineral filler.

SURFACE TREATMENT: An application of asphaltic material to any type of road or pavement surface covered with chips, pea gravel or sand.

CHAPTER II

PROVINCIAL PAVING SPECIFICATIONS

(Condensed Versions)

ALBERTA

Minister—Hon. W. A. Fallow

Deputy Minister—
G. H. N. Monkman

Highway Commissioner—
N. W. Macpherson

TYPE IN GENERAL USE: The type in general use is Bituminous Surface Treatment (Inverted Penetration Method), on a plant-mix waterproofed mechanically stabilized gravel base course. This surface treatment is subsequently given a Seal Coat or a Re-treatment.

PLANT-MIX WATERPROOFED MECHANICALLY STABILIZED GRAVEL BASE COURSE: This shall consist of an intimate mixture of gravel and/or crushed stone, sand, clay binder and water, integrally waterproofed by the incorporation of one per cent. of RC-1 Bituminous Waterproofing Material such as specified on page 22. This mixture shall be combined as hereinafter specified and shall be placed, compacted and finished upon the previously prepared subgrade in two layers, to the thickness, density, grade and cross-section specified.

GRADED AGGREGATE: The graded aggregate shall consist of a mixture of (1) crushed stone or crushed gravel and (2) sand, stone dust or other inert, finely divided mineral material, combined in such proportions that when mixed with clay binder the final mixture will conform to the requirements hereinafter specified. The graded aggregate shall be free from injurious quantities of flaky particles, loam, soft shale, organic matter or other deleterious material. It shall all pass a 1¼" round screen and shall be uniformly graded from coarse to fine so as to obtain high density.

SOIL BINDER: The soil binder shall consist essentially of fine particles of sand, silt and clay; shall be free from injurious amounts of organic matter and be of such character that when combined with the graded aggregate, a stabilized soil mixture will be provided with the proper balance of potential density and cohesion without risk of detrimental volume change. The soil binder shall have a plasticity index of 10 to 30.

WATER: The water shall be reasonably clean and free from substances which might render it unfit for use.

BITUMINOUS WATERPROOFING MATERIAL: This shall be RC-1 as specified on page 22.

WATERPROOFED STABILIZED GRAVEL MIXTURE: The finished mixture shall consist of the graded aggregate and soil binder, supplied individually or in combination to give the following gradations and requirements:

WATERPROOFED STABILIZED GRAVEL MIXTURE		
Passing	Per cent. Range	Per cent. Ideal
1¼" round screen	100	100
4 mesh sieve.....	40-75	60
10 mesh sieve....	30-55	45
40 mesh sieve....	15-33	25
200 mesh sieve...	6-16	11

The fraction passing the 40 mesh, without the bituminous material, shall have a plasticity index between 2 and 6. It shall have a liquid limit not exceeding 25. It shall not be less than 40 per cent. of the fraction passing a 10 mesh sieve. The faction passing a 200 mesh sieve shall not be more than ⅔ and preferably nor more than ½ of the fraction passing a 40 mesh sieve. In addition, the finished stabilized soil mixture shall contain approximately one (1) per cent. by weight of RC-1 bituminous material distributed throughout the mixture as a waterproofing agent. The clay binder shall be thoroughly pulverized by passing it through an approved close-set roll shredder or other approved methods to ensure its thorough comminution. No stablization construction shall be permitted when the temperature is 35°F. and falling.

SUBGRADE PREPARATION: No stabilized soil mixture shall be deposited on the roadway until the prepared subgrade has been approved by the Engineer.

MIXING: Mixing operations shall be carried out in an approved stationary mixing plant and the unit shall consist of a pugmill or other effective mixing equipment. The finished mixture shall be free from clay balls and uncoated material. The amount of water to be added shall be sufficient to raise the moisture content of the soil mixture to the optimum moisture and not more than two (2) per cent. above the optimum, and shall be determined by the Engineer. The mineral aggregate materials, water and bitumen shall be proportioned by a weigh batching system or other method approved by the Engineer. The properly batched mineral aggregate materials shall be placed in the mixing unit, together with the specified quantity of water, and mixed until thoroughly wetted. One per cent. of RC-1 shall then be added and mixing continued until a uniform mixture of aggregate, soil binder, bitumen and water is obtained.

SPREADING AND COMPACTING: The waterproofed stabilized base course mixture shall be laid by means of mechanical spreaders in two layers. Each layer shall be compacted to a minimum dry density of 140 lbs. per cubic foot by pneumatic tired rollers. Any ruts or irregularities formed in the surface during compaction of either layer shall be smoothed by blading during the rolling operations. The final moisture content of the mixture in each layer just before compaction shall be at least the optimum moisture for the mixture, as determined by the Engineer, and preferably one to two per cent. above the optimum to assist in rapid compaction. Final consolidation, however, must occur at the optimum moisture in order to obtain maximum density. If necessary, and as directed by the Engineer, water shall be added in such quantity and in such manner that the stablized material is brought to this moisture content during compaction. If required and as directed by the Engineer, layers shall be disced and harrowed during the moistening operations to ensure a uniform moisture content. The moisture shall be uniformly deposited, in the quantity specified for each layer. Each layer, after compaction, shall be allowed to dry throughout before the next layer is placed over it. Rollers for compaction of all layers shall be of pneumatic rubber-tired type. Rollers for the final rolling of the top layers shall be of the smooth steel surface type. The compacting unit of pneumatic tired rollers shall be not less than 60 inches in width and shall weigh not less than 250 lbs. per lineal inch of width. They shall be so constructed that the entire surface for the full width of the compacting unit shall be compacted at a single passage of the roller. The smooth steel roller shall be of self-propelling tandem type, weighing not less than 10 tons. The speed of rolling shall not exceed 4 miles per hour.

GENERAL: The Contractor may carry on the placing, spreading, compacting and shaping operations on sections of the roadway of convenient length, subject to the approval of the Engineer, but each layer must be thoroughly consolidated, finished and dried on a section, before the succeeding layer is placed. Whenever feasible the materials shall be hauled over portions of the completed or partially completed stabilized mat. Such hauling shall be done uniformly over the full width of the mat at vehicular speed restricted to a maximum of 20 miles per hour. The Contractor shall maintain the subgrade and each layer of the base constructed and repair at his own expense any failures which may occur, to the satisfaction of the Engineer. At no time may the base course be constructed over any section of the subgrade softened by rains, until the subgrade is again firm and dry. Plant-mix waterproofed mechanically stabilized gravel base course mixture will be paid for at the unit price bid per ton actually incorporated into the work and compacted to the density and thickness specified. Scales

for the weighing are provided, installed, maintained and checked at the Contractor's expense. Weighing is done by a Department employee.

PRIMING: If priming operations are called for they are carried out according to the following specifications. The roadway shall be swept to produce a clean surface. The asphaltic primer, for specifications see MC-1, page 22, shall be applied only when the surface is dry or but slightly damp and when the air temperature in the shade is not less than 50°F. Half the roadway width shall be primed at one time and as directed by the Engineer. The primer shall be applied by means of a pressure distributor of approved design, equipped with pneumatic tires, pressure gauge, volume measuring device and tachometer. It shall be designed to distrubute the contents in a uniform spray without atomization, to the amount and within the temperature range specified. Suitable means of determining the temperature of the asphaltic material shall be provided on the distributor. The normal width of application shall be 12′ with provision made to spray lesser widths. The spray bars shall be of the non-drip type. The distributor shall be equipped with a heating apparatus so that the asphaltic material can circulate during the heating process. A narrow spout pouring-pot or hose attachment shall be available to touch up those spots unavoidably missed by the distributor. The primer shall be sprayed at a temperature of 100-130°F. From 12 to 24 hours after the application of the primer or when the primer has been completely absorbed into the base, the final treatment for the bituminous surface treatment (inverted penetration method) shall be applied.

BITUMINOUS SURFACE TREATMENT (INVERTED PENETRATION METHOD): The roadway shall be cleaned, if necessary, and also patched where any holes have developed. These holes shall be cleaned of all loose material and a small amount of asphaltic binder (see specifications covering material for inverted penetration construction, page 19) placed in the bottom and the hole filled with the cleanest stone readily available. The stone shall be tamped until the asphaltic material flushes through. After patching, an amount of asphaltic binder, specified by the Engineer, shall be applied at a temperature of 125-150°F. under the general conditions specified under priming operations.

MINERAL AGGREGATE: The mineral aggregate used for the bituminous surface treatment shall be crushed gravel composed of sound, hard, durable particles and angular fragments, free from elongated material, vegetable and other deleterious matter. Depending on the particular project, it shall conform to one of the two following grading requirements.

1″ MINERAL AGGREGATE FOR SURFACE TREATMENT		
Passing	Held On	Per cent
1″ round screen		100
¾″ round screen		90–100
⅜″ round screen		20–50
¼″ round screen		0–10
	⅛″ round screen	100

¾″ MINERAL AGGREGATE FOR SURFACE TREATMENT		
Passing	Held On	Per cent
¾″ round screen		100
½″ round screen		80–90
¼″ round screen		5–25
	⅛″ round screen	100

The mineral aggregate shall be spread within 20 minutes of the application of the bituminous binder. It shall be obtained from stockpiles previously placed adjacent to the work and spread at a rate of approximately 350 cubic yards per mile or as specified by the Engineer.

SPREADING: The aggregate shall be spread by approved mechanical spreaders so that it is laid down ahead of the truck or the spreader wheels.

ROLLING: Immediately following the application of the aggregate rolling shall commence. A roller weighing not more than 5 tons shall be used. Rolling shall proceed in the standard method, in a longitudinal direction from the outer edges to the centre, each trip overlapping by half the width of the front wheel.

FINISHED SURFACE: Following the initial rolling, the surface shall be thoroughly broomed and rolling shall be continued until a smooth, compacted surface has been obtained. To prevent bleeding additional aggregate shall be applied where necessary, at the direction of the Engineer.

SHOULDERS: After the surface treatment (inverted penetration construction) has been completed, an application of the bituminous binder shall be applied to the shoulders at approxi-

mately 1/6 gallon per square yard, or in such amount as the Engineer deems necessary.

SEAL COAT OR RE-TREATMENT: This treatment is intended for application to the existing bituminous surface as it shows signs of wear. The mineral aggregate shall consist of crushed gravel composed of sound, hard, durable particles and angular fragments, free from elongated material, vegetable and other deleterious matter. Depending on the particular project, it shall conform to one of the following grading requirements:

¾″ MINERAL AGGREGATE FOR SEAL COAT	
Passing	Per cent
¾″ round screen	100
½″ round screen	80–90
¼″ round screen	5–25
⅛″ round screen	0

½″ MINERAL AGGREGATE FOR SEAL COAT	
Passing	Per cent
½″ round screen	100
⅜″ round screen	70–80
¼″ round screen	10–30
⅛″ round screen	0

CONSTRUCTION METHOD: All holes or depressions shall be repaired by the removal of loose material and replacing same with a suitable patching mixture which is compacted to produce a tight surface conforming to grade. Bumps and waves shall be removed by scarifying, blading and rolling or other approved means. The surface shall be swept clean by means of rotary brooms with blower attachment or other approved methods. Immediately following, the cut-back asphaltic material, conforming to specifications, shall be uniformly applied at a rate of approximately ¼ gallon per square yard or as directed by the Engineer. Application shall be made at a temperature of 100-140°F. and shall be carried out only when the surface is dry and air temperature not less than 50°F. in the shade. The bituminous material shall be applied by an approved type pressure distributor as previously specified. The mineral aggregate shall be spread immediately. It shall be clean and dry. It shall be uniformly distributed by

means of an approved type spreader at a rate of 20-30 pounds per square yard as directed by the Engineer. It shall be applied ahead of the truck or the spreader wheels. Immediately after spreading, the cover coat shall be thoroughly broomed by a drag broom and shall be rolled by a roller weighing not more than 5 tons. Rolling, accompanied by brooming, shall proceed in the standard method. The first rolling shall be completed within ½ hour of the spreading of the mineral aggregate and subsequent rolling shall continue until a smooth, thoroughly compacted surface has been obtained. Proper warning signs and barricades must be maintained for the protection of traffic. If necessary, flagmen and a pilot man must be provided to control traffic while operations are in progress.

	MC-1 PRIMER		MC-3 INVERTED PENETRATION†		MC-4 INVERTED PENETRATION†		SC-4 INVERTED PENETRATION‡		RC-1 STABILIZATION	
	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample
Water, % max.	0.0	.....	0.0	.....	0.0	.....	0.5	.....	0.0	.....
Specific Gravity 60°F.	.....	1.010	.....	1.055	.....	1.065	.....	1.075	.....	1.035
Flash Point, (O.C.) °F., min.	80	80	90	85	90	90	200	280	80	80
Softening Point (B&R) °F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Viscosity—Saybolt Furol										
At 122°F.	25–40	29	200–300	216	400–500	497	400–500	462	60–70	64
At 212°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Distillation, % By Volume Off										
At 374°F. min.	10 (Max.)	7.5	3	4.0	.....	1.0	.....	.....	8	9
At 437°F., min.	12	13.75	5	6.5	1	3.0	.....	.....	14	12.5
At 460°F., min.	20	15.75	7	8.0	4	5.0	.....	.....	16	13.75
At 500°F., min.	.....	17.75	.....	9.0	.....	5.5	.....	.....	.....	15.0
At 600°F., min.	.....	24	.....	13.0	.....	8.5	.....	.....	.....	18.0
At 680°F., max.	40	27.5	25	14.0	25	9.5	15	.....	35	19.5
Distillation Residue, % by Weight, min.	65	80.2	78	89	80	92.4	90	100	70	84.5
Softening Point (B&R) °F. min. (on Res.)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Penetration at 77°F., 100 grs. 5 sec. (on Res.)	100–300	131	100–300	110	100–300	130	.....	.....	160 (Max.)	108
Ductility at 77°F., min. (on Res.)	100	110+	100	110+	100	110+	100*	110+*	100	110+
Solubility in CS_2, % min.	99.5	99.85	99.5	99.8	99.5	99.78	99.5	99.82	99.5	99.83

*On Residue reduced to 100 Pen.
†Used in Inverted Penetration, with clean aggregate. The lighter viscosity (MC3) material used in cooler weather.
‡Used in Inverted Penetration, with dirty aggregate. SC5 sometimes used in hot weather.

BRITISH COLUMBIA

Minister—Capt. the Hon. C. S. Leary

Deputy Minister and Chief Engineer	*Acting Deputy Minister and Assistant Chief Engineer*
Arthur Dixon	H. P. Napier

TYPE IN GENERAL USE: The type in general use is Road-mix or Plant-mix Mulch constructed on a primed gravel base. The mulch course is surfaced by a Flush Coat with a Non-Skid Finish Aggregate.

PRIMING: The road shall be lightly graded to provide an even surface and all loose material shall be windrowed along each side. The priming bituminous material, type MC-1, see page 27, shall be sprayed on in the quantity directed by the Engineer. If necessary, mineral primer coat cover shall be applied. This shall be composed of mineral aggregate—100% passing the ¼″ screen. When the gravel road surface is in a loose or broken condition or when there is an excess of loose gravel on the surface and light grading is not practicable, road-mix mulch bituminous material, type MC-2, see page 27, shall be substituted for the priming bituminous material and mixed in by blading to form the primed surface.

ASPHALTIC MATERIAL: The asphaltic material used in the road or plant-mix mulch shall be of a type suitable for the particular job, see specifications on page 27 and 28.

Type	Construction	Application Temp.
RC-1	Surface Treatment—cold weather..	125-150°F.
RC-2	Surface Treatment—cool weather..	135-160°F.
RC-3	Surface Treatment—mod. weather..	150-175°F.
	Plant-mix, Open Macadam Aggregate.....	100-150°F.
RC-4	Surface Treatment—hot weather	160-185°F.
	Plant-mix, Open Macadam Aggregate.....	150-175°F.
RC-5	Surface Treatment—hot weather	175-225°F.
	Penetration.....	175-225°F.
MC-1	Priming.....	70-125°F.
MC-2	Road-mix, Dense Graded Aggregate	125-175°F.
	Carpet Coat.....	125-175°F.
	Cold Plant-mix, Dense Graded Aggregate.....	100-150°F.
MC-3	Road-mix, Retread.....	125-175°F.
	Cold Plant-mix.....	100-150°F.
MC-4	Hot Plant-mix, Cold Laid.....	160-200°F.
MC-5	Hot Plant-mix, Cold Laid.....	175-225°F.
M.I.P. (Mixed-in-Place)	Same as for MC-2.....	
SC-1	Dust Laying.....	100-125°F.
	Blotter Treatment.....	100-125°F.
SC-2	Blotter Treatment.....	125-150°F.
SC-3	Special Work.....	150-175°F.
SC-4	Special Work.....	175-200°F.
SC-5	Hot Plant-mix—Cold Laid—Dense Graded Aggregate.....	175-225°F.
	Surface Treatment.....	175-250°F.
Heavy Liquid	Hot Plant-mix, Cold Laid.....	175-250°F.
Asphalt	Surface Treatment.....	200-275°F.

MINERAL AGGREGATE: The mineral aggregate used for the mulch shall be clean, dry, crushed or screened or selected durable gravel or stone, and sand, all as approved by the Engineer, and shall conform to the following grading limits by weight:

MULCH MINERAL AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1″ screen	100
¼″ screen	35–70
10 mesh	25–50
200 mesh	0–10

ROAD-MIX MULCH: Approved mineral aggregate shall be spread upon the treated road surface to a uniform depth of 2½″ loose, or as directed by the Engineer. It shall be sprayed with the quantity of bituminous material ordered by the Engineer and then the whole course shall be suitably bladed until all particles of aggregate are uniformly coated with bitumen and completely mixed. The mixture shall then be spread to a smooth and uniform camber of 1 in 45, except at curves. The mixture shall be traffic compacted. A true surface shall be maintained by blading until the traffic marking ceases and then the surface shall be rolled with an approved gasolene roller weighing not less than 8 tons. Rolling shall be carried out according to generally accepted standard methods and no sharp turning of the roller wheels on the mulch surface shall be allowed. No mulch work shall be started without a suitable roller on the job. No material shall be left in stock-piles over night unless due to sudden adverse weather conditions, when it shall be windrowed to one side.

PLANT-MIX MULCH: The mineral aggregate specified and the bituminous material shall be thoroughly mixed in a suitable plant so that all particles of the mineral aggregate are completely coated with bitumen. The volume of the mineral aggregate and the volume of the bitumen (calculated at 60°F.) shall be measured separately for each batch. The quantity of bitumen used per cubic yard of mineral aggregate shall be as directed by the Engineer. The necessary measuring devices shall be designed to give accurate control at all times. The mixing process shall not be carried out on the road to be surfaced. Spreading, rolling and finishing operations shall be carried out in a similar manner to road-mix mulch construction.

FLUSH COAT WITH NON-SKID FINISH AGGREGATE: The mineral aggregate used for the non-skid finish shall be clean, dry, crushed or screened or selected durable gravel or stone conforming to the following grading requirements:

NON-SKID FINISH AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
¾″ screen	100
¼″ screen	15

CONSTRUCTION METHODS: The surface to be treated shall be dry and swept clean. The bituminous material of a suitable type, see page 27, shall be applied at a rate per square yard directed by the Engineer. Overlapping of the sprayed bituminous material at the ends of each distributor load shall not be permitted and any excess of material must be immediately removed. Immediately following the application of bituminous material, the surface shall be evenly covered with approved mineral aggregate in the quantity directed by the Engineer. Segregation of coarse and fine material shall not be permitted and any excess or deficiency shall be corrected at once. Immediately following the application of aggregate the surface shall be rolled by an 8 ton tandem gasolene roller. Machine brooming shall not be allowed until the surface is well rolled, and the mineral well bedded and set in the bitumen.

Specifications and Tests	ASPHALTIC MATERIALS						British Columbia			
	MEDIUM CURING						RAPID CURING			
	MC-1	MC-2	M.I.P.	MC-3	MC-4	MC-5	RC-1	RC-2	RC-3	RC-4
Water % max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flash Point (O.C.)°F., min.	80	80	90	80	80	80	80	80	80	80
Viscosity—Saybolt Furol at 122°F.	15–20	100–200	150–200	200–300	300–500	800–1200	60–70	100–200	200–300	300–500
Distillation, % by Volume Off										
At 374°F.	....	....	....	....	....	....	4+	....	....	....
At 437°F.	20—	10—	....	10—	5—	1—	10+	10+	6+	3+
At 460°F.	....	....	4+	....	....	....	....	....	....	....
At 500°F.	....	....	9+	....	....	....	....	....	....	....
At 600°F.	25+	15–25	....	15–25	10–20	5–15	20+	15+	12+	10+
At 680°F.	50—	30—	20—	30—	25—	20—	35—	30—	25—	25—
Distillation Residue, % by Weight	55+	70+	85+	70+	75+	80+	70+	75+	80+	80+
Softening Point °F. (B&R)	....	....	65+	....	....	....	....	....	....	....
Penetration at 77°F., 100 grs., 5 secs.	100–300	100–300	....	100–300	100–300	100–300	80–120	80–120	80–120	60–120
Ductility at 77°F., min.	100	100	100	100	100	100	100	100	100	100
Solubility in CS_2, % min.	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5

Specifications and Tests	SLOW CURING ASPHALTIC MATERIALS					British Columbia
	SC-1	SC-2	SC-3	SC-4	SC-5	HEAVY LIQUID ASPHALT
Water % max.	0.5	0.5	0.5	0.5	0.5	....
Flash Point (O.C.)°F., min.	150	150	150	150	150	300
Burning Point, °F., min.	....	....	....	....	....	350
Softening Point (B&R) °F.	....	....	....	....	60–100	....
Viscosity—Saybolt Furol						
At 122°F.	30–60	100–200	200–300	300–500	....	....
At 212°F.	....	....	....	....	....	95–105
Volatility at 250°F., 5 hrs., 50 g., max.	....	....	....	....	....	1.5
Distillation, % by Volume Off						
At 437°F., max.	....	5	5	5	5	....
At 600°F., max.	....	15	10	10	10	....
At 680°F., max.	50	25	20	20	20	....
Distillation Residue						
Float at 122°F.	50—	20+	20+	20+	20+	....
% by Weight, 100 Pen., min.	....	....	....	....	....	85
% by Weight, 50 Pen., min.	55	60	65	67	80	....
Ductility at 77°F. (50 Pen.) min.	100	100	100	100	100	100*
Solubility in CS_2, % min.	99.0	99.0	99.0	99.0	99.0	99.0
Solubility in 86° Naptha, min.	....	....	....	....	....	70
Mineral Matter (Ash) max.	....	....	....	....	....	1.0

*Ductility test is made on 100 penetration residue.

MANITOBA

Minister—Hon. Erick Willis

Deputy Minister—
M. A. Lyons

Chief Engineer—
T. T. Wilson

TYPE IN GENERAL USE: The type in general use is Bituminous Plant-Mix Surfacing spread to approximately 1750 tons per mile and 22′ width on tangents on a primed base and covered with a Seal Coat.

PRIMING: The base course shall be primed with asphaltic material prior to the laying of the bituminous plant-mix surfacing. Priming shall not be carried out on a wet or damp subgrade or when satisfactory penetration cannot be obtained. The material, conforming to specifications for SC-1, see page 32, shall be applied at a rate of 1/6 gallons per square yard and at a temperature of 120-150°F. Half the road width shall be treated at a time and a sufficient interval allowed for the applied material to penetrate before treating the second half. Penetration shall be considered attained when free bituminous material has been absorbed and vehicles can traverse the section without picking up or splashing.

ASPHALTIC MATERIAL: The asphaltic material used in the bituminous plant-mix shall conform to the general requirements as specified for the SC-5 type, see page 32. It shall be proportioned at 4 pounds per 100 pounds of mineral aggregate but this figure may be varied at the discretion of the Engineer.

MINERAL AGGREGATE: The mineral aggregate shall be gravel consisting of clean, hard, durable material, free from shale, clay, vegetable or other delcterious matter. A minimum of 35% of the total amount retained on the ¼″ screen shall be made up of crushed particles. The aggregate as supplied to the drier shall meet the following screen requirements:

MINERAL AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1″ round or ¾″ square	100
½″ mesh	60–80
¼″ mesh	35–55
10 mesh	25 min.
100 mesh	5–10
200 mesh	5 max.

BITUMINOUS PLANT-MIX SURFACING: The mineral aggregate shall be heated to a temperature of 170-200°F. and shall not contain more than 1½% of moisture when delivered to the mixer. The asphaltic material, conforming to specifications for SC-5, see page 32, shall be pre-heated to 160-200°F.

MIXING: The mixing shall be carried out in a pug-mill of approved design. The gravel and asphaltic material shall be weighed into the mixer. The gravel shall be introduced first, then the asphaltic material, and mixing shall continue until all the particles of the aggregate are coated and the whole mass has a uniform colour.

SPREADING: Vehicles used in hauling the material shall not be driven at more than 35 MPH and shall be equipped with dual wheels of such size that the gross load shall not exceed 500 pounds per inch width of the tire. The material shall be spread by means of a bituminous paver of approved design. No material shall be spread until the primed grade is in satisfactory condition with all hollows and depressions brought to required cross-section and rolled.

ROLLING: When the spread material has sufficiently set up to bear the weight of an 8 ton roller, rolling shall begin and continue in the standardized manner, overlapping the shoulders for a distance of at least 9 inches. Rolling shall continue until compaction is satisfactory to the Engineer.

FINISHED SURFACE: The finished surface shall be smooth, uniform and true to line and grade. It shall have a crown of ⅜″ per foot of width from shoulder to centre of roadway on tangents, or on curves as staked on the ground by the Engineer.

SEAL COAT: The aggregate used in seal coating shall consist of clean, hard, durable grains and must be free from shale, clay, etc. Of the total amount retained on the 10 mesh sieve, not less than 35% by weight shall be crushed material. It shall meet the following requirements:

AGGREGATE FOR SEAL COAT	
Passing	Per Cent
½″ round or ⅜″ square	100
10 mesh	35–55
100 mesh	0–6

ASPHALTIC MATERIAL: The asphaltic material shall conform to the general specifications as set down for the RC-3 type, see page 32.

CONSTRUCTION: In order to accommodate traffic the Contractor shall seal one-half the road width at a time in mile units or other units satisfactory to the Engineer. The surface shall be swept clean of all objectionable foreign matter. The asphaltic material shall be applied at the rate of ¼ gallon per square yard by a pressure distributor of approved design at a temperature of 100-125°F. A cover coat of 20 pounds per square yard of aggregate shall be applied immediately. When necessary, it shall be hand-broomed to insure even distribution. The cover aggregate shall be spread from trucks by an approved spreader that will operate in such a manner that the bituminous seal coat will not be disturbed. After distribution rolling shall be carried on with an 8 ton roller to imbed the mineral aggregate in the bituminous material. Payment shall be made on the basis of cubic yards of aggregate measured in the trucks before spreading and gallons of asphaltic material heated and distributed.

ANALYSIS OF TYPICAL PAVEMENT SAMPLE, BITUMINOUS MIX

GRADING:

Passing	Held On	Per cent		
1″ screen.	¾″ screen.	2.3		
¾″ screen.	⅜″ screen.	21.6		
⅜″ screen.	4 mesh	22.4	Coarse Aggregate.	46.3%
4 mesh	10 mesh	11.8		
10 mesh	20 mesh	15.8		
20 mesh	40 mesh	11.3		
40 mesh	80 mesh	4.1		
80 mesh	100 mesh	0.5	Fine Aggregate	43.5%
100 mesh	200 mesh	1.1		
200 mesh		2.8		
Fines by decantation		2.3	Fines	6.2%
Total Mineral Aggregate		96.0		96.0
Bitumen—SC-5		4.0		4.0
TOTAL		100.0		100.0

	SC-1 ASPHALT PRIMER††		M.I.P. ROAD MIX		RC-3 SEAL COAT		SC-5 PLANT MIX	
	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample
Water, % max.	0.0	O.K.	0.0	O.K.	0.0	O.K.	0.5	O.K.
Specific Gravity 60°F., min.	.975	.9954	....	1.034	....	1.04	1.000	1.07
Flash Point, (O.C.) °F, min.	200	255	90	90	80	105	200	305
Softening Point (B&R) °F.	....	....	....	....	....	....	....	....
Viscosity—Saybolt Furol								
At 122°F.	(Max.) 60	58	150–250†	225	200–300†	287	....	....
At 160°F.	....	....	....	....	....	....	338–415†	397
At 212°F.	....	....	....	....	....	....	....	....
Distillation, % by Volume Off								
At 374°F., min.	....	....	....	....	....	6	....	....
At 437°F., min.	....	....	3	3	9	8.5	....	....
At 500°F., min.	....	....	....	6.5	....	11.5	....	....
At 600°F., min.	....	2.5	7	12.5	12	14.5	(Max.) 2.0	....
At 680°F.. max.	....	10.5	20	16.0	25	16.5	7.0	5.5
Distillation Residue % by Weight, min.	....	92.6	85	88.4	80	88.2	95	97.4
Residue reduced to 100 pen., % by Weight	60*	61.5*	....	85.4*	....	87.8*	....	88*
Softening Point (B&R) °F., (on Res.)	....	....	75–100	98.5	....	119	....	90
Penetration at 77°F., 100 grs., 5 sec. (on Res.)	....	....	....	217	80–120	89	....	210
Float Test 122°F., min. (on Res.)	....	....	....	228	....	520	60	220
Volatility 325°F., 50 grs., 5 hrs., % loss wt., max. (on. Res.)	8*	8.2*	....	15.6*	....	12.8*	....	5.4*
Ductility at 77°F., 5 cm./sec., min. (on Res.)	100*	100+*	100*	100+*	100	100+	100**	100+*
Ductility at 39°F., 1 cm./sec., min. (on Res.)	....	....	....	10+*	....	20+	6**	10+*
Solubility in CS_2, % min.	99.5	99.6	99.5	99.5	99.5	99.7	99.5	99.5
Bitumen Insoluble in 86° B. Naptha % min.	7	....	....	....	....	....	14	....

*Test is on residue reduced to 100 penetration.
**Test is on residue reduced to 125 penetration.
All Asphalt Material supplied shall meet the requirements of the "Arizona" Demulsibility Test to the satisfaction of the Engineer.
†The Government has the option to request the supplier to have shipments toward the high or low limit of the Viscosity range depending on climatic conditions.
‡The SC-1 material shall not foam when heated to a temperature of 250°F.

NEW BRUNSWICK

Minister—Hon. W. S. Anderson

Deputy Minister—
A. W. Barbour

Chief Engineer—
C. B. Croasdale

TYPE IN GENERAL USE: Plant-Mix Asphaltic Concrete laid to a specified quantity of 330 pounds per square yard on a primed graded gravel base, covered with a Plant-Mix Seal Coat at from 30 to 40 pounds per square yard.

PREPARATION OF THE SUB-BASE AND PRIMING: The gravel used in the preparation of the sub-base shall consist of hard, sound, durable stone of various sizes ranging uniformly from coarse sand to a maximum particle size of 2½". The clay or other satisfactory binding material shall not exceed 10% by dry weight of the mass. This gravel shall be spread on the grade to such depth, loose, that when compacted by rolling the thickness shall be as shown on the plans or as ordered by the Engineer. When a compacted gravel base of more than 4" is required, the material shall be spread and rolled in courses not exceeding 4". Fine grading and trimming, as required to bring the surface to true sub-grade, shall be carried on by re-scarifying, re-shaping and re-rolling just before priming operations commence or by the application of additional gravel. This will make it possible to have the primed gravel base course true to established line and grade. The asphalt primer shall be applied at ¼ to ½ gallon per square yard at temperatures of 60-120°F. as directed. It shall not be applied in wet weather or at temperatures lower than 45°F. or on a wet sub-grade or whenever, in the opinion of the Engineer, either the weather or the sub-grade is unsuitable. The primer shall be allowed to penetrate for such time as the Engineer directs and unsatisfactory areas shall be repaired as they develop. The primer shall be applied by an approved pressure distributor in a uniform manner at the rate directed. The distributor shall be equipped with pneumatic tires and its loaded weight imposed on the sub-grade shall not be in excess of 500 pounds per inch width of tire.

FORMS: Suitable side forms of wood or steel shall be firmly fastened in place, true to line and grade. These shall remain in place until reasonable compaction has been obtained and the mixture is stable and resists lateral displacement under further rolling. Immediately after the forms are removed and before any further rolling is done, approved shoulder material shall be placed against the finished edge. The final compaction of both shoulder and pavement shall be obtained by continued rolling.

ASPHALTIC MATERIAL: The asphaltic material used in the asphaltic concrete and surface seal mixtures shall be of P.M.H. type with a softening point (R&B) of 80-100°F. For specifications covering these and asphaltic material for priming please see page 42.

MINERAL AGGREGATE:

COARSE AGGREGATE: The coarse aggregate shall be crushed gravel or crushed stone consisting of clean, hard, sound, durable particles free from flat or elongated pieces and clay. When tested according to the Los Angeles Abrasion Method, the coarse aggregate shall not show a loss of more than 35% by abrasion. If gravel is used as coarse aggregate it shall contain approximately 50% of crushed particles. The coarse aggregate shall meet the following screen requirements:

COARSE AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1¼″ round	100
¾″ square	60–80
⅜″ square	20–35
4 mesh	0–5

FINE AGGREGATE: The fine aggregate shall consist of natural sand or crushed particles composed of clean, tough, durable grains free from objectionable amounts of clay, loam or other foreign material. The fine aggregate is used alone for the plant-mix seal coat and in combination with material from the plant stone bin for the asphaltic concrete mix. The fine aggregate shall meet the following screen requirements:

FINE AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
4 mesh	95–100
30 mesh	30–55
100 mesh	15–35
200 mesh	6–25

COMBINED AGGREGATE: The combined aggregate, coarse and fine mixture, shall meet the following screen requirements:

COMBINED AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1¼″ round	100
¾″ square	70–85
⅜″ square	50–70
4 mesh	35–55
30 mesh	15–28
100 mesh	7–17
200 mesh	3–12

PLANT-MIX ASPHALTIC CONCRETE: The proportions of the aggregates shall be within the following composition limits:

	Asphaltic Concrete	Surface Seal
Coarse Aggregate	45–65%	—
Fine Aggregate	30–50%	90–93%
Bitumen P.M.H.	3½–5 %	5½–10%

The coarse and fine aggregates are dried and heated at the paving plant so that when delivered to the mixer they are at a temperature of 175-250°F., as directed by the Engineer. The coarse aggregate shall not hold more than ¼ of 1% of moisture and the fine aggregate not more than ½ of 1% of moisture. The asphalt shall be separately heated to 150-225°F. After leaving the drier, the hot aggregate is passed over a plant screen to separate it into not less than two sizes, the screen being of such size and capacity that the dry aggregates are effectively separated into the specified fractions, none of which shall contain more than 5% of particles which would properly belong to the other fraction or fractions. The weighing hopper must have sufficient capacity to hold the maximum amount of aggregate for one batch. Scales for the weighing hopper must be of either dial or beam type and if of the beam type, they must be equipped with a precision indicator and must be sensitive to ½ of 1% of the maximum required load. As well, there must be a separate beam for each size aggregate and a tare for balancing the hopper. The asphalt bucket must have a capacity of not less than 10% of the batch weight. It must be suspended on dial scales, which read in increments of one pound and are sensitive to ½ pound. The asphalt shall be delivered to the aggregate in the mixer in such a manner that after the specified mixing time has elapsed, samples taken from different parts of the mixer shall not differ by more than 2/10 of 1%.

MIXING: The mixer shall be of the twin shaft pug-mill type. The clearance of the blades from all fixed or moving parts shall not exceed 2″. The mixing cycle for asphaltic concrete is set at 45 seconds and that for plant-mix seal at 60 seconds after all material is in the mixer, or such time as is required to completely mix the batch.

SPREADING: The mixture shall be deposited directly from the truck to the spreader box of an approved self-propelled paving and finishing machine. The use of spreader box alone will not be permitted nor will hand spreading be allowed. The mixture shall not be laid unless the subgrade is dry or at least free from standing water and only when weather conditions are favourable. No mixture shall be laid when the air temperature is below 35°F. except by permission of the Engineer. Placing of the mixture shall be as continuous as possible and the roller shall pass over the unprotected edge only when the laying of this course is to be discontinued for such time as will permit the mixture to become set. When traffic is not diverted from the section under construction and the pavement is laid in two strips, each one-half the full width of the road, the two strips are to be carried forward in alternate stretches, as closely together as possible so that the material of the second strip may be bonded to that of the first strip along the centre line of the pavement, thus preserving the proper bond and contour of the whole.

ROLLING: Initial rolling shall be carried out with a power-driven tandem roller. All other rollers required shall be power-driven three-wheel rollers of at least 10 tons. Rolling shall be in the standard method, longitudinally from edges toward centre, overlapping, with runs of slightly different length. The speed of the roller shall not exceed 3 miles per hour and shall at all times be slow enough to avoid any displacement of the mixture. Displacement from any cause whatsoever, shall be at once corrected by the use of rakes and fresh material where required. Rolling shall be at a rate not exceeding 20 tons per hour per roller and shall continue until all roller marks are eliminated and further compression not possible. During an eight hour day, each roller must be engaged in actual rolling not less than 6½ hours. Along curbs, headers, manholes and such places not accessible to the roller, compaction shall be obtained by the use of tampers, and at all contacts of this character the joints between these structures and the surface mixture must be effectively sealed.

JOINTS: When work is discontinued for any length of time or between the work of successive days, joints between the old and new sections shall be carefully made in a manner to give a thorough and continuous bond. Joints shall be constructed by laying and rolling against planks which are the thickness of the compacted mixture and which are placed

across the entire width of the pavement, or by such methods as may be approved by the Engineer. When laying the mixture is resumed, the planks are removed and fresh mixture raked against the joint and thoroughly compacted with tampers and roller.

PLANT-MIX SEAL COAT: As soon as possible after the asphaltic concrete has received a preliminary rolling and when the course will bear the weight of the roller without undue displacement, the surface seal is spread uniformly thereon at the rate specified. Satisfactory uniformity may be secured with an experienced operator by casting the material in a direction longitudinal to the pavement, or by spreading with rakes or lutes. Immediately after the spreading, rolling shall be continued with three wheel rollers as outlined before.

FINISHED SURFACE: The pavement shall be smooth and true to the established crown and grade. It shall present a surface of uniform texture with no evidence of segregation or insufficiently sealed areas. It shall have an average thickness of 3.10 to 3.25 inches and shall at no point be less than 2.87 inches. The surface shall be free from irregularities exceeding ¼″ as measured with a 10′ straight-edge paralleling the centre line of the roadway. Any defective places shall be remedied by cutting out the material at such points and replacing with fresh mixture, or by the addition of fresh mixture which shall be immediately compacted to conform with the surrounding area to which it shall be thoroughly bonded.

STANDARDS IN NEW CONSTRUCTION:

Width of right-of-way	66 feet
Minimum road width	30 feet
Minimum pavement width	20 feet
Shoulders	4–5 feet
Maximum curve	5 degrees
Maximum grade	8 per cent

Curves greater than 2° are superelevated.
Curves greater than 5° are widened.

PLANT-MIXED GRAVEL MULCH: A considerable mileage of this type has been constructed in the Province on roads where a cheaper type of surfacing than plant-mix asphaltic concrete was deemed desirable. The gravel mulch is laid on a previously prepared, primed sub-grade at approximately 300 pounds per square yard.

PREPARATION OF THE SUB-BASE AND PRIMING: Immediately prior to the application of the primer the contractor shall fine grade the consolidated gravel sub-base and shall roll the shaped base course with a three-wheeled roller

of not less than 10 tons. When primer is applied the base course shall be true to established line and grade and shall have the contour of the finished paved surface. Priming shall be carried out according to specifications previously stated.

ASPHALTIC MATERIAL: The asphalt primer shall conform to the Department's specifications for asphalt primer, page 42. The asphalt used in the gravel mulch shall conform to current specifications issued by the Department, page 42.

MINERAL AGGREGATE: The mineral aggregate shall consist of crushed stone or crushed gravel, with or without the addition of natural sand. It shall be clean, sound and free from coatings of clay or other deleterious material. That portion retained on the ¼″ screen shall contain at least 40% of crushed particles and shall yield a loss on abrasion, by the Los Angeles Method, of not more than 35%. The aggregate shall meet the following screen requirements:

MINERAL AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1″ round	100
4 mesh	45–75
30 mesh	20–40
200 mesh	2–12

During any single day's run the aggregate supplied to the mixer shall not vary more than 10% on the 4 mesh sieve or more than 3% on the 200 mesh sieve.

PLANT-MIXED GRAVEL MULCH: The proportions of the aggregate by weight shall be within the following composition limits as directed by the Engineer:

	Per cent
Aggregate	94.5–96.5
Bitumen	3.5– 5.5

The maximum permissible variation in bitumen content from the specified amount shall be 4/10 of 1%. The plant used for manufacturing paving mixture shall be of a type approved by the Engineer and shall be provided with separate chambers for drying and mixing the constituents. If the plant is of the continuous mixer type the method of measurement shall be by

volume and the plant equipped with positive adjustable feeding devices by means of which the quantities of aggregate and bituminous material may be accurately measured. The aggregate shall be surface dry when delivered to the mixer and shall not contain moisture in excess of ½ of 1%.

MIXING: If the plant is of the batch type, the dry aggregate shall be charged into the mixer, the bitumen added and mixing continued for a period of at least 30 seconds, or longer if necessary, to produce a mixture of uniform colour in which all the particles of the mineral aggregate are completely coated with bitumen. If the plant is of the continuous mixer type, the rate of discharge from the mixer shall be so regulated that the mixture discharged is uniform in colour with all particles completely coated with bitumen. In either case, samples drawn from different parts of the batch after discharge from the mixer shall not differ in bitumen content by more than 2/10 of 1%.

SPREADING: The mixture shall be placed in the manner such as specified for asphaltic concrete. As forms are not used, approved shoulder material shall be brought up to the pavement edge for a width of at least 8″, previous to preliminary rolling.

ROLLING: Initial rolling may be carried out with a power-driven tandem roller. Shoulder material must be rolled in conjunction with the pavement. The surface shall be given a second rolling not less than twenty-four hours after the initial rolling, as directed by the Engineer. Rolling specifications are essentially the same as for asphaltic concrete.

JOINTS: Joints shall be constructed in accordance with specifications for asphaltic concrete.

FINISHED SURFACE: The pavement shall be smooth and true to established crown and grade and shall present a surface of uniform texture with no evidence of segregation. It shall not vary in thickness by more than 10%. Any defective places shall be remedied by cutting out the material at such points and replacing with fresh mixture, or by the addition of fresh mixture, which shall be immediately compacted to conform to the surrounding area to which it shall be thoroughly bonded.

LIQUID ASPHALT SEAL COAT:

MINERAL AGGREGATE: The cover material shall consist of clean, sound, hard and durable fragments. The rock from which this material is obtained shall have a loss on abrasion, Los Angeles Method, of not more than 25%. It shall conform in size to the following screen requirements:

STONE CHIPS FOR SEAL COAT	
Passing	Per cent
5/8″ square	100
4 mesh	15
8 mesh	5

The cover material shall be free from dust in such quantity to prevent adherence of the liquid bitumen to the coarse particles. If necessary, it must be washed to remove excess dust. Approximate quantities to be used in construction are:

Liquid bituminous material	.25-.30 gal. per sq. yd.
Stone chips	25-30 lbs. per sq. yd.

CONSTRUCTION: Construction shall be by the single application method. The surface shall be swept clean and free of any dirt or other foreign material adhering to it before bituminous material is applied. At the time of application the surface must be thoroughly dry and the air temperature not less than 45°F. The bituminous material, see page 42, shall be applied by an approved type pressure distributor at a uniform rate and at a temperature from 100-175°F. as directed by the Engineer. The spray bar shall be of such dimensions that one-half the full width of the pavement may be treated in a single operation. An excessive or insufficient quantity of bitumen at junction points will not be tolerated. Care must be taken along the centre line to ensure the application of the second half contiguous to the first without overlapping, to prevent an excess of bituminous material at the joint. Any sections which have not received a full covering shall later receive an application with a hand spray but this practice is to be avoided if possible. Immediately following any application of bituminous material the stone chips shall be uniformly spread over the surface by means of an approved spreader which by spreading the chips in advance of the spreader's movement eliminates tracking. Immediately following any application of mineral cover the surface shall be rolled with a three-wheel, power-driven roller weighing not less than 5 tons. If required by the Engineer a broom drag shall be attached behind the roller to ensure uniformity of cover.

FINISHED SURFACE: The completed surface, after rolling, shall present a uniform appearance, shall be true to crown and grade and shall show no irregularities of more than ¼″ under a 10′ straight-edge parallel to the centre line of the roadway.

ANALYSIS OF TYPICAL SAMPLES

		Asphaltic Concrete	Surface Seal	Carpet Coat
Density		2.365	2.315	2.410
Stability, 3¾″ ring		6750	—	3900
Stability, 1¾″ ring		—	2865	—
Temperature at plant		230	265	—
Temperature at road		225	255	—
Bitumen variation from formula		0.0	0.0	0.0
Grading				
Passing	Held On	Per cent		
—	1¼″ round	0.0	0.0	0.0
1¼″ round	¾″ square	7.3	0.0	8.0
¾″ square	⅜″ square	29.3	0.0	34.6
⅜″ square	4 mesh	19.3	4.8	14.3
4 mesh	8 mesh	12.4	15.7	9.2
8 mesh	14 mesh	7.7	12.3	7.7
14 mesh	28 mesh	6.2	14.9	7.5
28 mesh	48 mesh	4.7	15.4	5.3
48 mesh	100 mesh	4.3	15.7	3.3
100 mesh	200 mesh	2.3	8.2	1.6
200 mesh	—	2.5	6.3	4.0
Total		96.0	93.3	95.5
Bitumen		4.0	6.7	3.8
Water		0.0	0.0	0.7
Total		100.0	100.0	100.0

Specifications and Tests — ASPHALTIC MATERIALS — New Brunswick

	CARPET COAT ASPHALT		ASPHALT SEAL COAT		ASPHALT PRIMER		P.M.H. ASPHALT CEMENT*	
	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample
Water, % max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Specific Gravity, 60°F., min.	....	1.011	....	....	.950	.973	1.00	1.042
Flash Point (O.C.) °F., min.	90	110	80	115	90	95	300	425
Softening Point (B&R) °F.	....	....	....	....	....	....	80–100	91
Penetration 77°F., 100 grs., 5 sec., max.	....	....	....	....	....	....	....	....
Float Test 140°F., min.	....	....	....	....	....	....	90	....
Volatility 325°F., 50 grs., 5 hrs., % loss wt., max.	....	....	....	....	....	....	1.0	0.84
Viscosity—Saybolt Furol								
At 122°F.	100–150	142	150–500	213	15–25	24	....	....
At 212°F.	....	....	....	.. .	....	....	....	....
Distillation, % by Volume Off								
At 374°F., min.	3	5.0	2.0	5.0	4	8.5	....	....
At 437°F., min.	6.5	10.5	6.5	7.5	11	17.0	....	....
At 500°F., min.	10.5	15.0	9.0	12.0	19	28.5	....	....
At 680°F., max.	25	22.5	25.0	16.5	40	31.5	....	....
Distillation Residue, % by Weight, min.	80	81.4	80	84.8	66	72.5	....	....
Softening Point (B&R) °F., min. (of Res.)	100	106	....	107	100	107	....	....
Penetration at 77°F.,100 grs.,5 sec., max. (of Res.)	90–130	130	100–150	106	200	134	....	....
Ductility at 77°F., min.	100	100+	100	100+	100	100+	†	100+
Solubility in CS_2, % min.	99.5	99.8	99.5	....	99.5	99.8	99.5	99.8

*The Asphalt Cement shall not foam when heated to 347°F. (175°C.).

†When the material is evaporated to 100 penetration residue, this residue shall have a Ductility at 77°F., 5 cms. per minute of not less than 100 cms., and at 39°F., 1 cm. per minute, of not less than 10 cm.

NOVA SCOTIA

Minister—Hon. J. D. MacKenzie

Deputy Minister—
R. W. McColough

Chief Engineer—
J. E. Belliveau

TYPE IN GENERAL USE: Plant-Mix Asphaltic Dense Aggregate laid to a specified quantity of 300 pounds per square yard on a primed graded gravel base. A Surface Treatment of chips shall be applied at such time as deemed necessary.

PREPARATION OF THE SUBGRADE, BASE COURSE GRAVEL, BASE COURSE AND PRIMING: A typical grading and paving project usually requires three years to complete. The first year, construction is limited to heavy grading; the second year, to underdrainage construction and the application of base course gravel. Paving operations are carried out the third year. A spring frost check-up is made at the beginning of the second year and again in the third year, this being necessary for the purpose of determining the amount of gravel and under drainage necessary. The base course shall be unscreened pit or beach gravel, screened gravel, crushed gravel or crushed stone consisting of hard, durable particles with a sufficient amount of suitable binding material included. It shall meet the following screen requirements:

BASE COURSE
SCREEN REQUIREMENTS

Passing	Per cent
3″ round	100
2″ round	80–100
1″ round	50–70
¼″ round	20–30

BASE COURSE AND PRIMING: The base course shall be graded to the line and grade shown on the plans or as directed, and shall have no irregularities exceeding plus or minus ½″ as checked longitudinally by a 10′ straight-edge or laterally by a template having a crown 1/96 of its width. The priming bitumen shall be applied at a rate of between 1/6 and

1/3 gallon per square yard, as directed by the Engineer, and at a temperature of 60-120°F. It shall not be applied in wet weather or at temperatures lower than 45°F., nor shall it be applied whenever, in the opinion of the Engineer, the weather or surface is unsuitable. The bituminous material shall be allowed to penetrate for such time as the Engineer will direct and if unsatisfactory areas develop they shall be patched. The primer shall be applied by an approved type pressure distributor in a uniform manner and at such rate as required. This distributor must be equipped with pneumatic tires and its loaded weight, as imposed on the subgrade, must not be more than 500 pounds per inch of tire width.

ASPHALTIC MATERIAL: The asphaltic material used in the plant-mix shall be of P.M.H. type and shall be in the proportion of 4 pounds per 100 pounds of mineral aggregate, which quantity may be varied as directed by the Engineer. Specifications covering this, as well as priming, sealing and penetration asphaltic materials, are tabulated on page 49.

MINERAL AGGREGATE: The mineral aggregate for the paving mixture shall consist of crushed gravel composed of clean, sound, hard and durable particles, well graded in size within the limits specified. That fraction retained on a ¼″ round screen shall contain a minimum of 50% crushed particles. The gravel, before crushing, shall show a percentage of wear not exceeding 10 when tested according to the Deval Method. If crushed rock is used it shall show a percentage of wear of not more than 6 when tested according to the Deval Method. The total clay content shall not exceed 1½%. The aggregate shall meet the following screen requirements:

PAVING MIXTURE AGGREGATE SCREEN REQUIREMENTS

Passing	Per cent
1″ round	100
½″ round	60–80
¼″ round	40–55
10 mesh	20–30
100 mesh	5–10
200 mesh	0–5

PLANT-MIX ASPHALTIC DENSE GRADED AGGREGATE: The mineral aggregate shall be thoroughly dried, free of all moisture and heated to a temperature of 200°-250°F. The P.M.H. asphalt shall be heated to a similar temperature. The mineral aggregate shall be screened and placed in two separate bins, one containing the aggregate passing a 1″ round

screen and retained on a ¼″ round screen and the other containing the aggregate passing a ¼″ round screen. The mineral aggregate from the two bins shall be recombined in proportions to yield a mixture within the specified grading limits, having a uniformity satisfactory to the Engineer. The aggregate and liquid asphalt for each batch shall be carefully and separately weighed before being placed in the mixer.

MIXING: The mixer shall be a pug-mill type, of capacity and design satisfactory to the Engineer. The aggregate and asphalt shall be deposited in the mixer at temperatures within the specified heating limits, the mineral aggregate first and the asphalt added. Each batch shall be mixed until all particles of the aggregate are coated with asphalt and the whole mass is of uniform colour. A minimum mixing time of 45 seconds is required. Before introducing the asphalt, the mineral aggregate in the mixer must be uniform throughout as to grading within the limits specified.

SPREADING: The mixed material shall be spread directly on the primed gravel base course to such width and full weight per square yard as specified, by means of approved self-propelling spreading or finishing machines.

ROLLING: Rolling operations shall proceed when the material has set sufficiently to bear the weight of a 10 ton roller. Rolling shall begin longitudinally at the sides overlapping the shoulders for a distance of at least one foot, and proceed toward the centre of the surface course, each successive trip over-lapping by one-half the width of the rear wheel. Such rolling shall continue until the surface is compacted to the satisfaction of the Engineer. It shall be continued from day to day until there is no further displacement of the surface. The rollers shall be approved diesel, gas or steam. The pressure under the rear wheels of rollers shall not be less than 500 pounds per inch width of wheel. From June 1 to September 1, there shall be not less than one gas or diesel roller per 200 tons per 8 hour day; from September 1 to June 1, not less than one gas or deisel roller per 100 tons per 8 hour day. Three steam rollers are deemed to be the equivalent of two gas or diesel rollers.

FINISHED SURFACE: The finished surface shall have a cross-section with a crown 1/96 of its width unless otherwise specified. It shall be smooth. It shall show no irregularities of more than ¼″ under a 10′ straight-edge used longitudinally or more than ¼″ under a template used in checking the cross-section.

PENETRATION MACADAM: A considerable mileage of this type has been constructed in the Province. It is made up of a 2½″ wearing course on a specially prepared base course.

BASE COURSE: The base course shall be composed of broken stone conforming to the following specifications and shall be of such width and depth, after rolling, as directed. The broken stones for the base course shall consist of clean, durable crushed rock, having a percentage of wear of not more than 4 (Deval Method) equivalent to a French coefficient of wear of not less than 10 and a toughness of not less than 8 (A.S.T.M. tests). It shall be free of flat or elongated pieces and uniformly graded to conform to the following requirements:

BROKEN STONE FOR BASE COURSE	
Passing	Per cent
2¾″ round	100
1½″ round	0–30
1″ round	0–5

This broken stone shall be uniformly spread and thoroughly rolled. Then the course shall be bonded with clean sand or stone dust of the following requirements:

STONE DUST SCREEN REQUIREMENTS	
Passing	Per cent
½″ round	100
¼″ round	80–100
100 mesh	10–25

After being thoroughly rolled the sand or stone dust shall be just below the top of the broken stone and none shall be left on top of the stone.

SURFACE COURSE: The surface course shall consist of broken stone (coarse aggregate having a percentage of wear of not more than 3 and a toughness of not less than 12). It shall pass a 2¾″ round screen and be retained on a 1½″ round screen. This coarse aggregate shall be spread from vehicles or a dumping board by hand or by mechanical spreaders. Power graders will not be permitted. The material shall not be dumped within the area over which it is to be spread. The material shall be shaped to the proposed cross-section and rolled until the surface is true and unyielding, by a roller weighing not less than 10 tons at a rate not exceeding 80 cubic yards of broken stone per 8 hours per roller. The presence of clay or other foreign matter will not be tolerated. The stone must be perfectly dry and clean before the bituminous material

is applied. This bituminous material, see page 49, shall be applied at a rate of 1.6 to 1.7 gallons per square yard per 2½″ compacted surface course. The surface shall be rolled while still warm, care being taken to keep the bituminous material from adhering to the wheels of the roller.

KEYSTONE: The keystone shall conform in size to the following requirements:

KEYSTONE FOR SURFACE COURSE	
Passing	Per cent
1″ round	100
¾″ round	10–25
¼″ round	0

The keystone shall be added in small quantities while rolling continues and shall be distributed by brooming. Only a sufficient quantity to properly chink the surface shall be used. Low air temperatures will necessitate more rolling. An excess of bituminous material on the shoulders will not be permitted in order that they may be rolled in conjunction with the surface course.

SEAL COAT: Cover material shall conform in size to the following requirements:

CHIPS FOR SEAL COAT	
Passing	Per cent
¾″ round	100
¼″ round	0–20

The seal coat shall be evenly applied on a clean-swept surface, in the same manner as the penetration coat and at a rate of 1/3 gallon per square yard, and immediately covered with stone chips and rolled while warm. The finished surface shall have a cross-section with a crown 1/96 of its width unless otherwise specified. It shall be smooth. It shall show no irregularities or more than ¼″ under a 10′ straight-edge used longitudinally or more than ¼″ under a template used in checking the cross-section.

ANALYSIS OF TYPICAL PAVEMENT SAMPLE (PLANT-MIX ASPHALTIC DENSE GRADED AGGREGATE):

Density	2.405
Stability, 3¾″ ring	6700#
Temperature at plant	255°F.
Temperature at road	250°F.
Bitumen variation from formula	−0.1%

GRADING

Passing	Held On	Per cent
	1″ round	0.0
1″ round	½″ round	31.4
½″ round	¼″ round	20.6
¼″ round	10 mesh	16.0
10 mesh	14 mesh	4.7
14 mesh	28 mesh	7.9
28 mesh	48 mesh	6.2
48 mesh	100 mesh	2.8
100 mesh	200 mesh	1.7
200 mesh		4.9

Total Mineral Aggregate	96.2
Bitumen	3.8
Water	0.0
Total	100.0

	1A—ASPHALT PRIMER		3A—PLANT MIX		4A—PENETRATION		5A—ASPHALT SEAL	
	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample
Water % max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Specific Gravity 60°F., min.	.975	.986	1.000	1.036	1.000	1.023	.975	1.000
Flash Point (O.C.) °F., min.	90	90	300	430	500	505	90	115
Softening Point (B&R) °F., min.	....	....	75–90	88	110	118	....	....
Penetration 77°F., 100 grs., 5 sec., max.	....	....	....	....	85–100‡	89	....	....
Float Test 140°F., min.	....	....	....	....	....	....	....	....
Volatility 325°F., 50 grs. 5 hrs., % loss wt., max.	....	....	1.0	0.64	1.0	0.21	....	....
Viscosity—Saybolt Furol								
At 122°F.	15–20	24	....	....	....	....	100–250*	220
At 212°F.	....	....	150–450	192	....	....	....	....
Distillation, % By Volume Off								
At 374°F., min.	2	9	....	....	....	....	...	6.5
At 437°F., min.	7	17	....	....	....	....	2.5	10.0
At 500°F., min.	12	28	....	....	....	....	9.0	13.0
At 680°F., max.	37	31.5	....	....	....	....	25	17.5
Distillation Residue, % By Weight min.	70	72.4	....	....	....	....	80	85.5
Softening Point (B&R) °F., min.	100	108	....	....	....	....	100	108
Penetration at 77°F., 100 grs., 5 sec., max.	160	125	....	....	Min. 70	77	100–120	128
Ductility at 77°F., min. cms.	100	100+	†	100+	80	100+	100	100+
Solubility in CS_2, % min.	99.5	99.8	99.5	99.8	99.5	99.8	99.5	99.8

*With Type 5A, Grade "A", cool weather application, Viscosity of 100-150; Grade "B", warm weather application, Viscosity of 200-250. Temperature of application 150-200°F.

†With Type 3A, when the material is evaporated to 100 penetration residue, this residue shall have a Ductility at 77°F., 5 cms. per minute, of not less than 100 cms., and at 39°F., 1 cm. per minute, of not less than 6 cms.

‡With type 4A Penetration 77°F., 100 grs., 5 sec.; Oct. 1st-Apr. 30th., 100-120.

ONTARIO

Minister—Hon. T. B. McQuesten

Deputy Minister—
R. M. Smith

Chief Engineer—
A. A. Smith

TYPES IN GENERAL USE:

1. HOT-MIXED HOT-LAID

(a) HL-1 Trap Rock Asphaltic Concrete Surface Course.
(b) HL-2 Stone-Filled Sheet Asphalt Wearing Course
(c) HL-3 Asphaltic Macadam (mixed) and Black Base
(d) Binder Course

2. PENETRATION

3. PLANT-MIX MULCH

4. ROAD-MIX MULCH

5. BITUMINOUS RETREAD SURFACE COURSE

PRIME COATING and SURFACE SEALING are used in the construction of many of these different types.

PRIME COATING: The road surface shall be cleaned by mechanical sweepers and/or hand brooms, as required by the Engineer, to expose but not dislodge the embedded stone. Bituminous Priming Material (MC-1), see page 10, shall be uniformly sprayed on the road surface at 60-125°F. by means of an approved pressure distributor. The air temperature must be higher than 50°F. and surface conditions satisfactory. The distributor must be equipped with tachometer, thermometer, etc. and hand hose attachment or pouring pots to apply primer to areas unavoidably missed. The primer shall be applied at 0.2-0.4 gallons per square yard as directed by the Engineer and quantities shall be based on material at 60°F. Bitumen shall be sprayed over one-half the road width only and for the distance directed by the Engineer. The second half of the road shall be treated later when directed. No prime coat may be applied prior to May 15 or after September 30, except by special permission. If specified the prime coat may be covered with 10-15 pounds per square yard of clean, dry mineral aggregate uniformly distributed by approved mechanical spreaders. It shall be distributed ahead of truck or spreader wheels and not later than one hour after the primer has been applied. If deemed necessary, rolling and brooming shall be carried out until a smooth and compacted surface is obtained.

MINERAL AGGREGATE: Sand for bituminous construction shall consist of hard, tough, durable particles and shall meet the following screen requirements as closely as possible:

Passing	Held On	Per cent
8 mesh....	... 30 mesh....	 20
30 mesh....	... 50 mesh....	 27
50 mesh....	... 80 mesh....	 30
80 mesh....	...100 mesh....	 15
100 mesh....	...200 mesh....	 7
200 mesh....	.....	 1

CUSHION SAND: Cushion sand shall not contain more than 10% by weight of clay or loam. It must be clean and sharp, not having more than 10% retained on the 8 mesh sieve.

MINERAL FILLER: The mineral filler shall be thoroughly dry limestone or other approved mineral dust with 100% passing the 30 mesh and not less than 65% passing the 200 mesh.

CRUSHED GRAVEL: Crushed gravel shall consist of tough, durable rock, free from flat, elongated particles and not containing more than 5% of soft, friable material, clay, loose or adhering dust, vegetable loam or other deleterious matter. It shall meet the following screen requirements:

Passing	Held On	Per cent
¾″ round or ⅝″ square....	.....	 100
.....	..¼″ round or ³⁄₁₆″ square....	70–80
¼″ round or ³⁄₁₆″ square....	.....	20–30

CRUSHED STONE: Crushed stone shall be bedded rock or boulders containing not more than 5% of soft material. Particles coated with dust or having edges worn off shall provide cause for rejection of the material. The stone shall be tested for toughness, wear and absorption and classified as follows:

Grade	Toughness	Coefficient Wear	Absorption Lbs. per cu. ft.
A	not less than 18	not less than 14	not more than 0.6
B	not less than 10	not less than 7	not more than 1.0
C	not less than 7	not less than 5	not more than 1.5
D	is a rock that does not meet the requirements of any of the above and may be used only on consideration of the Engineer.		

(NOTE: The French coefficient of wear equals 40 divided by per cent of wear by the Deval Method.)

Crushed stone is classified according to the following:

Class	Commercially Known As	Passing		Held On	
		Round	Square	Round	Square
1	½″ stone	1″	⅞″	½″	7/16″
2	1″ stone	1¾″	1½″	1″	⅞″
3	2″ stone	2½″	2⅛″	1¾″	1½″
4	4″ stone	4″	3½″	2½″	2⅛″
5	3″ penetration	3″	2⅝″	1¾″	1½″

CRUSHER RUN STONE: Crusher run stone shall have a maximum size of 2½″ round or 2⅛″ square with not more than 8% passing ¼″ round or 3/16″ square.

STONE CHIPS: Stone chips, commercially known as ⅜″ stone chips, shall have 100% passing ½″ round or 7/16″ square with the larger size predominating. The material shall be free from dust.

SCREENINGS: Screenings shall be the material from crushing 100% of which will pass a ⅜″ screen.

1. HOT-MIXED HOT-LAID TYPES OF PAVEMENT:

(a) HL-1 TRAP ROCK ASPHALTIC CONCRETE SURFACE COURSE: This type shall be composed of crushed trap rock or other approved aggregate mixed with 61/70 or 71/80 penetration asphalt cement, sand and mineral filler. It shall be laid upon compacted asphalt mixed macadam binder course or other prepared pavement base to a finished minimum thickness of at least 1″.

COARSE AGGREGATE: The coarse aggregate shall be suitable trap or other high quality stone, clean and free from dust, with no excess of flat or elongated pieces and meeting the following screen requirements:

COARSE AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
¾″ screen	100
¼″ screen	25 max.
1/8″ screen	5 max.

FINE AGGREGATE: The fine aggregate shall be approved sand and mineral filler.

COMBINED AGGREGATE AND MIXTURE: The combined aggregate and mixture shall meet the following composition requirements:

COMBINED AGGREGATE SCREEN REQUIREMENTS		
Passing	Held On	Per cent
¾″ screen	¼″ screen	35–65
¼″ screen	10 mesh	0–10
10 mesh	40 mesh	10–20
40 mesh	200 mesh	10–15
200 mesh		5–10
ASPHALT CEMENT		5-8

(b) HL-2 STONE-FILLED SHEET ASPHALT WEARING COURSE: This type is composed of broken stone, sand and stone dust mixed with 61/70 or 71/80 penetration asphalt cement. It is laid upon a binder course to a finished minimum thickness of 1½″.

COARSE AGGREGATE: The coarse aggregate shall be tough, durable stone meeting the following screen requirements:

COARSE AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
½″ screen	95 min.
¼″ screen	25 max.
10 mesh	2 max.

FINE AGGREGATE: The fine aggregate shall be approved sand and mineral filler.

COMBINED AGGREGATE AND MIXTURE: The combined aggregate and mixture shall meet the following composition requirements:

COMBINED AGGREGATE SCREEN REQUIREMENTS		
Passing	Held On	Per cent
½″ screen	10 mesh	15–25
10 mesh	40 mesh	15–30
40 mesh	80 mesh	20–40
80 mesh	200 mesh	15–25
200 mesh		5–10
ASPHALT CEMENT		8–10

The proportions shall be varied, within the limits designated, by the Engineer.

(c) HL-3 BASE COURSE ASPHALTIC MACADAM (MIXED METHOD) AND BLACK BASE: The types of approved mineral aggregate shall be mixed with ashpalt cement and laid in one or more courses, each to a compacted thickness of 3″ or as directed by the Engineer.

MINERAL AGGREGATE: The mineral aggregate shall be crushed gravel or stone of uniform quality, free from an excess of flat or elongated pieces. When gravel is used, at least 25% of the portion retained on the ¼″ screen shall consist of crushed particles. The mixture shall conform to the following composition requirements by weight but may be varied within these limits by the Engineer.

MINERAL AGGREGATE SCREEN REQUIREMENTS		
Passing	Held On	Per cent
1½″ screen..	... 1″ screen..	10–35
1″ screen..	...¼″ screen..	30–50
¼″ screen..	...10 mesh...	10–30
10 mesh...	.....	10–20
ASPHALT CEMENT..... 4–6		

(d) BINDER COURSE: Binder course shall consist of coarse mineral aggregate and sand uniformly mixed with asphalt cement and laid upon a prepared foundation to a compacted thickness of not less than 1″.

COARSE AGGREGATE: The coarse aggregate shall be broken stone or gravel of uniform quality, free from dust and an excess of flat elongated pieces. When crushed gravel is used, at least 60% of that portion retained on the ¼″ screen shall consist of crushed particles. The grading of the coarse aggregate shall meet the following screen requirements:

COARSE AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1¼″ screen.....	.....97 min.
½″ screen.....	.....30 max.
¼″ screen.....	..... 5 max.

FINE AGGREGATE: The fine aggregate shall be approved sand.

COMBINED AGGREGATE AND MIXTURE: The combined aggregate and mixture shall meet the following composition requirements as directed by the Engineer:

Coarse aggregate retained on 10 mesh..	55-70%
Fine aggregate passing 10 mesh.....	25–40%
Asphalt cement.....	4–6%

GENERAL FOR ALL HOT-MIX HOT-LAID TYPES: Samples of dust, sand and asphalt cement proposed to be used by the Contractor shall be submitted to the Department for approval. The asphalt cement shall conform to the penetration limits set by the Engineer for the material. It shall be stored in properly designed storage tanks and never heated above 300°F.

PREPARATION: Coarse aggregate and sand shall be heated and dried in a revolving type drier and delivered to the mixer at 250-300°F. A registering pyrometer shall be installed at the discharge end of the drier. The hot coarse aggregate and sand or fines shall be batch measured by accurate weighing; likewise, the asphalt cement and, when it is used, the mineral filler. The mixer shall be of approved pug-mill design. The mineral aggregate shall be first mixed dry for a period of 15-30 seconds. The asphalt cement shall then be added and mixing continued for 30 seconds or until such time as necessary to produce homogeneous mixtures with all the particles uniformly coated. Mixtures shall be transported to the road at the following temperatures:

Black base (open type).....	200–300°F.
Asphaltic concrete surface or binder (closed type)..	250–350°F.
Binder and top sheet asphalt.....	275–375°F.

SPREADING: Mixtures shall be delivered to the road only when the base is dry and weather conditions suitable. Spreading shall be by approved self-propelling mechanical finishers. Rakers shall be available to take care of inequalities in the spreading. Contact edges of curbing, gutters, manholes and cut-back joints of cold pavement shall be painted with a thin coating of hot asphalt cement before the mixture is placed against them.

ROLLING: While still hot and as soon as the mixtures can bear the weight without undue displacement, the surface shall be compressed by a three-wheel power roller of at least 10 tons. Rolling shall be according to standard methods and, when required, diagonal rolling in two directions shall be carried out. Rolling on surface course types and binder course must not exceed 150 square yards per hour per roller and for asphaltic macadam (mixed method) and black base must be at an average

rate of not more than 150 tons per day per roller and shall continue until no further compression is possible. Roller wheels must be kept slightly moistened with oil or water but an excess will not be permitted. Rolling of banked curves shall commence at the lower edge and advance by laps across the curve to the higher edge. Places impossible to compact with the roller shall be thoroughly compacted with hot tampers.

FINISHED SURFACE: After compaction the pavement shall be true to established crown and grade and shall show no irregularities of more than ¼″ under a 10′ straight-edge.

FORMS: When laying pavement where there is no curb or edging, planks shall be laid and firmly secured in place along the pavement edges to prevent lateral displacement of mixtures during the entire rolling.

2. **BITUMINOUS PENETRATION PAVEMENT:** If so directed the foundation surface shall be swept clean and primed. When aggregate is supplied from wayside quarries the surplus screenings and No. 2 stone shall be placed so as to strengthen the foundation of the road. Forms 6″ wide and 3″ deep shall be spiked to the foundation, 20′ apart and true to line and grade. When the road is clean and dry a course of clean No. 5 stone shall be laid to a thickness to give a compacted depth of 3″. This stone may carry a maximum of 20% of No. 2 stone. Rolling by a roller weighing at least 10 tons shall be carried out until the fragments present an even surface. If any irregularities or depressions appear they shall be picked loose and material added or removed. Where uneven grading of stone is apparent such sections shall be removed and replaced with stone conforming to the specifications. Immediately after rolling bituminous binder shall be sprayed over the surface at a pressure of 20-50 pounds per square inch by a pressure distributor of approved design. The quantity used in the first application shall be 1.40 to 1.65 gallons per square yard as directed by the Engineer. When joining with previous work uniformity shall be secured by using building paper to avoid an excess or deficiency of asphalt. The bituminous material shall be sprayed at the following temperatures:

120-140 penetration Binder B	275–350°F.
RC-5	200–225°F.

CHINKING PENETRATION COURSE: The sprayed surface shall be immediately covered with a layer of clean No. 2 stone (chinking stone), then rolled at once with a roller weighing at least 10 tons which has 22″ rear wheels and an approved broom attachment. Additional stone shall be applied and broomed in until all the voids in the No. 5 stone course are filled. Rolling shall be continued until the surface is even and true to established grade and contour. The road shall then be swept clean of all particles of stone not held by the bituminous binder and an application of between 0.2 and 0.4 gallons per

square yard of the same type of bituminous binder as previously used shall be sprayed. This shall be covered immediately by a layer of No. 1 stone spread by mechanical spreader. This course shall be rolled as before and additional No. 1 stone added to fill voids where necessary. The finished surface must not show any irregularities exceeding ¼″ under a 10′ straight-edge. Within four weeks after completion of this operation, the pavement shall be given a final seal coat as described in specifications for bituminous surface treatment.

3. PLANT-MIX MULCH: The bituminous mixture shall consist of mineral aggregate and bituminous binder combined as herein specified.

MINERAL AGGREGATE: The mineral aggregate shall be crusher run stone meeting the following screen requirements:

Passing	Per cent
¾″ round screen	100
¼″ square screen	30 max.

If crushed gravel is used it shall conform to the following specification for "A" grade gravel. It shall contain a large percentage of pebbles of igneous rocks and shall not contain more than 5% by weight of clay or loam. It shall have a coefficient of wear of not less than 14. It shall meet the following screen requirements:

Passing	Per cent
¾″ round screen	95 min.
¼″ square screen	45 max.

ASPHALTIC MATERIAL: The percentage used shall be from 3½-6½% by weight of the mixture as directed by the Engineer and shall be one of the following types: SC-5, SC-3, MC-3 or MC-4.

MIXING: If SC-5 is used mixing shall be carried out at temperatures of 175-225°F. and if any of the other types are used from 100-150°F. The material shall be placed in a mixer of approved design and mixing shall be continued until all particles are uniformly coated with bituminous binder.

SPREADING: The mixture shall be spread uniformly over the prepared and primed roadway in one or two courses in such quantities that, when finally compacted, the bituminous surface course shall have the required thickness. Approved bituminous pavers, pneumatic power graders or multiple blade maintainers shall be used to spread the mixture.

ROLLING: At such time after spreading as directed by the Engineer, the mixture shall be rolled by a roller of approved design weighing at least 5 tons. If slight irregularities develop during rolling these shall be removed by power grader or multiple blade drag.

SEAL COAT: When required and not less than four weeks after the wearing course has been compacted the pavement shall be given a seal coat as described in specifications for bituminous surface treatment.

FINISHED SURFACE: The finished surface must not show any irregularity exceeding ¼″ under a 10′ straight-edge.

4. ROAD-MIX MULCH:

BASE COURSE: The existing base shall be well-bonded, thoroughly and evenly compacted and true to established contour and grade. It should be constructed 1′ wider than the finished surface and, if directed, shall be shaped to provide thickened edges for the bituminous surface course. It shall be primed in accordance with the specifications for priming. Priming shall not be carried out more than seven days before the laying of the surface.

MINERAL AGGREGATE: Upon the primed surface, graded aggregate shall be spread to a uniform thickness of 3″ or less as directed by the Engineer and kept within 1′ of the pavement limits until mixing has been completed. The graded aggregate shall consist of broken stone or crushed gravel of a quality equal to grade "C" crushed stone and shall meet the following screen requirements:

Passing	Per cent
¾″ round screen	100
¼″ square screen	30

If crushed gravel is used it shall conform to the following specification for "A" grade gravel. It shall contain a large percentage of pebbles of igneous rocks and shall not contain more than 5% by weight of clay or loam. It shall have a coefficient of wear of not less than 14. It shall meet the following screen requirements:

Passing	Per cent
¾″ round screen	95 min.
¼″ square screen	45 max.

MIXING: The bituminous binder of M.I.P. type shall be uniformly sprayed by means of a pressure distributor at 80-

125°F. and only when the aggregate is reasonably dry and the air temperature above 50°F. It shall be applied at from 0.3 to 0.7 gallons per square yard as directed by the Engineer. Immediately after spraying, mixing shall be carried on by multiple blade drags, power graders or other types of approved mixers. Then the mixture shall be spread to uniform depth over the prescribed reduced width of roadway and a second application of bitumen made at the same rate and in the same manner as before. Mixing shall be continued and if a third application is deemed necessary the Engineer shall decide the quantity required.

SPREADING: When mixing is completed the mixture shall be spread over the entire width of road surface to uniform depth and width by a wheel base spreader not less than 10′ in length, and bladed to a smooth and even contour. Accumulation of coarse material along the sides shall be bladed longitudinally toward the centre to produce an even surface texture across the full width of the road.

ROLLING, SEAL COAT, FINISHED SURFACE: The same methods are used as in the construction of plant-mix mulch.

5. BITUMINOUS RETREAD SURFACE COURSE: This type of pavement is laid upon a base of suitable thickness and width, previously treated with bituminous primer if so directed. It shall be constructed to a finished thickness of 2″ to 3″ as directed by the Engineer.

MINERAL AGGREGATE: The mineral aggregate shall consist of crushed stone of reasonable uniformity, at least equal to grade "C" crushed stone. It shall be clean and free from excess dust and flat or elongated pieces. It shall meet the following screen requirements:

CRUSHED STONE SCREEN REQUIREMENTS	
Passing	Per cent
1¾″ round screen	95–100
1″ round screen	25–75
¼″ round screen	5–10

ASPHALTIC MATERIAL: The asphaltic material used shall conform to the specifications for RC-2, RC-3, MC-2 or MC-3 and shall be applied at 100-150°F. as directed by the Engineer.

MIXING: The coarse aggregate shall be spread to an uncompacted depth of 3½″ on the primed grade. The outer edges

shall be straight and kept one foot inside the limit of the edge of the finished pavement. Before spraying the spread aggregate shall be uniformly levelled. When reasonably dry and when the air temperature is not below 50°F. the aggregate shall be sprayed with bituminous binder from an approved type pressure distributor at a rate of 0.3 to 0.5 gallons per square yard as directed by the Engineer. Road mixing as specified for road-mix mulch shall then be carried out. The material shall be levelled and a second application of the same type binder applied at 0.3 to 0.4 gallons per square yard and mixing continued until all mineral particles are uniformly and thoroughly coated.

ROLLING: The mixture shall be thoroughly consolidated as described in specification for plant-mix mulch.

ALTERNATE PLANT-MIX METHOD: The coarse aggregate may be mixed in an approved plant with the bituminous binder at a rate of 3-5% as directed. The aggregate must be thoroughly dried and mixing continued until all the coarse aggregate is coated and the mixture homogeneous. The mixture shall be spread by power grader or other approved device to a depth that will give the specified finished thickness after compaction.

SEAL COAT: Within four weeks the surface shall be cleaned and a seal coat of fine aggregate conforming to the following grading requirements applied:

SEAL COAT AGGREGATE
SCREEN REQUIREMENTS

Passing	Per cent
¾″ round screen	100
½″ round screen	90–100
⅛″ round screen	0–5

The method for seal coating is that described in specifications for Bituminous Surface Treatment. The asphaltic material shall be applied at a rate of 0.2 to 0.4 gallons per square yard and the mineral aggregate spread by approved methods at 15-30 pounds per square yard.

FINISHED SURFACE: The surface of the finished pavement shall not vary from finished grade by more than ¼″ when measured by a 10′ straight-edge parallel to the centre line of the roadway.

BITUMINOUS SURFACE TREATMENT SEAL COAT: The road surface shall be cleaned by mechanical sweepers and/or by hand, as required by the Engineer, to expose but not dislodge the embedded stone. A pressure distributor of the

same type as required for priming operations shall be used. Building paper shall be spread over the road surface for a sufficient distance back so that the spraying nozzles are all operating at full force when the untreated surface is reached. The building paper shall then be removed and destroyed. Operations shall be carried out only when the surface is dry and the air temperature is higher than 50°F. The rate of application of bituminous material shall be as directed by the Engineer, based on net gallons at 60°F. The treatment may be in one or more applications as is directed. The various grades of bituminous surface treating material shall be applied according to the following table:

APPLICATION TEMPERATURES	
Type	Temperature Range
RC-1 & RC-2.....	..... 60–125°F.
RC-3.....	.....100-150°F.
RC-4 & RC-5.....	.....175–225°F.

When heavy material is used at temperatures above 200°F. the Contractor shall be paid an additional ½c per gallon. Immediately following the spraying of the bituminous material, a cover coat of the clean, dry mineral aggregate shall be uniformly distributed by means of approved mechanical spreaders at a rate of 15-20 pounds per square yard as directed by the Engineer The cover coat shall be spread ahead of the truck or spreader wheels and shall be thoroughly broomed by means of a drag broom. It shall be rolled with a power roller weighing at least 4 tons. Rolling, accompanied by brooming, shall continue until a smooth, thoroughly compacted surface has been obtained. Complete surface treatment shall be carried out on one-half of the road width at a time. The other half shall be treated when the Engineer so directs. No surface treatment may be carried out prior to May 15 or after September 30, except by special permission.

UNIVERSITY OF TORONTO
DEPARTMENT OF CIVIL ENGINEERING
Municipal and Structural

Specifications* and Tests — ASPHALTIC MATERIALS — Ontario

	G.D.L.	SC-1 A.D.L.	MC-1 PRIMER	M.I.P. MULCH	MC-3 MULCH	MC-4 MULCH	RC-3 SEAL	RC-4 SEAL	RC-5 SEAL	160/170 PEN.	71/80 PEN.	61/70 PEN.	CRACK FILLER
	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample
Water %	....	....	....	....	....	....	....	....	....	....	....	....	....
Specific Gravity, 60°F.	0.968	0.983	....	....	....	....	....	....	....	....	....	....	....
Flash Point	235	205	85	110	100	160	85	80	90	520	....	....	....
Initial Boiling Point	520	....	....	....	....	....	....	....	....	....	....	....	....
Softening Point (B&R) °F.	....	....	....	....	....	....	....	....	....	110	132	127.5	142.5
Penetration 77°F., 100 grs., 5 sec.	....	....	....	....	....	....	....	....	....	163	72	63	46
Float Test 140°F.	....	....	....	....	....	....	....	....	....	....	....	....	....
Volatility 325°F., 50 grs., 5 hrs., % Loss Wt.	....	....	....	....	....	....	....	....	....	.292	....	....	....
Viscosity—Saybolt Furol													
At 122°F.	....	44	19	109	221	582	292	550	....	....	....	....	....
At 212°F.	....	....	....	....	....	....	....	....	71	....	....	....	....
Viscosity—Saybolt Universal, at 130°F.	115	....	....	....	....	....	....	....	....	....	....	....	....
Distillation, % by Volume Off													
At 374°F.	....	0.0	16	2	2.5	0.5	2	4	10	....	....	....	....
At 437°F.	....	0.0	23	9	8	3.0	12	10	14	....	....	....	....
At 500°F.	....	Trace	25	15	11	9.0	13	15	17	....	....	....	....
At 560°F.	....	8.5	31	17.5	15.5	12.0	22	17.5	18.5	....	....	....	....
At 600°F.	....	16.0	33	20	17.5	14.0	24.5	19.5	19.5	....	....	....	....
At 680°F.	....	21.0	36	23	21	17.5	26	22	20.5	....	....	....	....
Distillation Residue, % by Wt.	....	....	....	....	....	....	....	....	....	....	....	....	....
Softening Point (B&R) °F., (of Res.)	....	Soft	100	85	116	127	115	122	116	....	....	....	....
Penetration at 77°F., 100 grs., 5 sec. (of Res.)	....	"	140	....	233	211	161	120	114	140	....	....	....
Ductility at 77°F.	....	"	100+	....	100+	100+	100+	100+	100+	100+	100+	37	20
Solubility in CS_2, %	....	....	....	....	....	....	....	....	....	99.9	....	....	....

*Ontario Department of Highways Specifications are tabulated in Chapter I on pages 7 to 13.

PRINCE EDWARD ISLAND

Minister—Hon. J. P. McIntyre

Deputy Minister—
L. B. MacMillan

Chief Engineer—
C. F. H. MacDonald

TYPE IN GENERAL USE: Plant-Mix Asphaltic Dense Graded Aggregate shall be laid to a specified quantity of 300 pounds per square yard on a primed, graded gravel base. A surface treatment of sand or chips shall be applied at such time as deemed necessary.

PREPARATION OF THE SUBGRADE AND PRIMING: The grading contractor shall complete all heavy grading work the year before paving construction is commenced. On completion of the grading contractor's work, approximately 800 cubic yards of gravel per mile shall be spread. A spring check-up will show where additional underdrainage and gravel base course construction are necessary and when this work is completed, the standard gravel base course shall be put on and bituminous primer applied. The standard for base course gravel construction is the same as that specified for Nova Scotia insofar as quality and grading requirements are concerned. Before any of this is put down, shoulders shall be built of sufficient width and height to hold the base course in place and permit rolling of at least 12″ of the shoulders simultaneously with the rolling of the base course. Priming methods and quantities are essentially the same as those of Nova Scotia. The section primed shall be two to three feet wider than the width of the finished pavement. One-half the road width shall be primed at a time and care taken to direct traffic down the unprimed half until the primer has penetrated well. This usually takes from 2 to 3 hours. Then the second side shall be primed and traffic restricted to the drier half of the road. These precautions will eliminate a considerable amount of ravelling which would result from vehicular traffic on the wet primed grade. Paving shall not be permitted until the prime has cured for at least 48 hours.

ASPHALTIC MATERIAL: The asphaltic material used in the plant-mix shall be of P.M.H. type and shall be proportioned at the rate of 4 pounds per 100 pounds of mineral aggregate, which quantity may be varied as directed by the Engineer. Specifications covering this, as well as for primer and seal coat asphaltic materials, are tabulated on page 65.

MINERAL AGGREGATE: The mineral aggregate shall conform to the same specifications as used in Nova Scotia, except that the gravel shall be tested by the Los Angeles Abrasion Method (A.S.T.M. C131-39) and shall not show a loss of more than 30% by abrasion. Total clay content shall not exceed 1½%. The aggregate shall meet the following screen requirements:

PAVING MIXTURE AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
1″ round	100
½″ round	60–80
¼″ round	40–55
10 mesh	20–30
100 mesh	5–10
200 mesh	0–5

PLANT-MIX ASPHALTIC DENSE GRADED AGGREGATE: Specification details covering the drying, screening, weighing, mixing, spreading, rolling and finished surface are the same as those for Nova Scotia.

ANALYSIS OF TYPICAL PAVEMENT SAMPLE (PLANT-MIX DENSE GRADED AGGREGATE):

		PLANT MIX	CHIP SEAL	SAND SEAL
Density		2.376	—	—
Stability, 3¾″ ring		5600#	—	—
Temperature at plant		240°F.	—	—
Temperature at road		230°F.	—	—
Bitumen variation from formula		+0.1%	—	—
Pounds per square yard		—	31.1	20.7
Gallons per square yard		—	0.25	0.18
Grading				
Passing	Held On	Per cent		
	1″ round	0.0	0.0	0.0
1″ round	½″ round	21.4	10.0	0.0
½″ round	¼″ round	26.4	64.3	2.9
¼″ round	10 mesh	16.9	23.4	20.6
10 mesh	14 mesh	3.8	2.3	16.9
14 mesh	28 mesh	4.5	0.0	23.3
28 mesh	48 mesh	4.6	0.0	25.2
48 mesh	100 mesh	7.4	0.0	9.4
100 mesh	200 mesh	3.9	0.0	0.9
200 mesh		6.4	0.0	0.8
Total Mineral Aggregate		95.2	100.0	100.0
Bitumen		4.8	—	—
Water		0.0	—	—
Total		100.0		

Specifications and Tests — ASPHALTIC MATERIALS — Prince Edward Island

	RC-3 SEAL COAT		MC-1 ASPHALT PRIMER		SC-5 PLANT MIX	
	Specification	Sample	Specification	Sample	Specification	Sample
Water % max.	0.0	0.0	0.0	0.0	0.0	0.0
Specific Gravity, 60°F., min.	....	1.011	.975	.976	1.000	1.009
Flash Point (O.C.)°F., min.	90	120	90	95	300	480
Softening Point (B&R) °F.	....	....	....	....	75–90	89
Penetration 77°F., 100 grs., 5 sec., max.	....	....	....	....	....	....
Float Test 140°F., min.	....	....	....	....	....	....
Volatility 325°F., 50 grs., 5 hrs., % loss wt., max.	....	....	....	....	1.0	0.40
Viscosity—Saybolt Furol						
At 122°F.	200–300	207	15–20	25	....	....
At 212°F.	....	....	....	....	150–450	271
Distillation % by Volume Off						
At 374°F., min.	5	5.0	2	11.0	....	....
At 437°F., min.	8	9.0	7	18.0	....	....
At 500°F., min.	12	14.0	12	27.0	....	....
At 680°F., max.	25	17.0	37	33.0	....	....
Distillation Residue, % by Weight, min.	80	86.0	70	71.0	....	....
Softening Point (B&R) °F., min.	100	106	100	107	....	....
Penetration at 77°F., 100 grs., 5 sec., max.	160	110	160	122	....	....
Ductility at 77°F., min.	100	100+	100	100+	*	100+
Solubility In CS_2, % min.	99.5	....	99.5	99.8	99.5	99.8

*With Type SC-5, when the material is evaporated to 100 penetration residue, this residue shall have a Ductility at 77°F., 5 cms. per minute, of not less than 100 cms., and at 39°F., 1 cm. per minute, of not less than 6 cms.

QUEBEC

Minister—Hon. T. D. Bouchard

Deputy Minister—
Arthur Bergeron

Chief Engineer—
Ernest Gohier

TYPE IN GENERAL USE: Plant-Mix Dense Graded Bituminous Concrete, shall be laid to a specified thickness of not less than 2″ on a primed, graded and consolidated or stabilized gravel base and surface treated with a Plant-Mix Seal Coat at from 20 to 40 pounds per square yard, or Squeegee Seal Coat.

PRIMING: Priming shall be carried out only when the weather conditions are judged suitable by the Engineer; never in rainy weather or at temperatures below 45°F. Spraying shall be done in widths up to 15 feet as required. The primer shall be applied at a rate of ¼ to ½ gallon per square yard and at 60-120°F. The general specifications for primer are identical to those used in New Brunswick, Nova Scotia or Prince Edward Island.

FORMS: Wooden or steel forms which will give the specified compacted thickness of pavement shall be used. These shall remain in place until final compaction. When the forms are taken up, backfilling shall be done immediately and the material shall be compacted so that the shoulder elevation will be ¼″ higher than the edge of the pavement.

MINERAL AGGREGATE: The coarse aggregate shall be crushed gravel or stone. If crushed stone, the particles must be clean and hard, without dust, clay or organic matter. Flat and elongated pieces are not acceptable. Loss by abrasion shall not exceed 6 when tested according to the Deval Method. A Decantation Test (A.S.T.M.M.C. 117-37) for material passing 200 mesh shall not show an excess of ½ of 1%. If crushed gravel, there shall be 50% of crushed particles in the fraction held on the ¼″ round screen. The loss by abrasion when tested according to the Los Angeles Method shall not exceed 28%. If deemed necessary by the Engineer the gravel must be washed.

The fine aggregate shall be either sand or fine gravel consisting of clean, hard, angular particles, free from clay and organic matter. There must be no balled-up material when delivered to the mixer. The fine aggregate shall meet the following screen requirements:

FINE AGGREGATE SCREEN REQUIREMENTS		
Passing	Held On	Percent
4 Mesh		95–100
4 Mesh	10 Mesh	15–40
10 Mesh	80 Mesh	30–60
80 Mesh	200 Mesh	8–20
200 Mesh		2–10

COMBINED AGGREGATE: The combined aggregate coarse and fine mixture, shall meet the following screen requirements:

COMBINED AGGREGATE SCREEN REQUIREMENTS		
Passing	Held On	Percent
1″ round		100
1″ round	¼″ round	40–60
1″ round	½″ round	20–40
½″ round	¼″ round	15–25
¼″ round	10 Mesh	10–20
10 Mesh	80 Mesh	15–30
80 Mesh	200 Mesh	5–10
200 Mesh		1–5

ASPHALTIC MATERIAL: The asphaltic material used in the bituminous concrete shall be 90°F. M.P. It shall be residual asphalt derived from the distillation of asphaltic petroleum. For specifications covering this material see page 71. The bituminous primer shall consist of asphalt cement dissolved in a petroleum distillate. For specifications see page 71. The liquefier if used in this mixture, shall be a petroleum disstillate and a good solvent for the asphalt cement. It shall conform to the following requirements:

Initial Boiling Point (Minimum).....200°F.
Final Boiling Point (Maximum) .....500°F.
Minimum spread between boiling points.....200°F.
Water..... 0%

PLANT-MIX DENSE-GRADED BITUMINOUS CONCRETE: The proportions of the aggregates, based on a specific gravity of 2.70, shall conform to the following:

Fraction	Percentages		
	Bituminous Concrete	Surface Seal	Variations
Coarse Aggregate.	40–60		± 2
Fine Aggregate. . .	35–55	91–95	± 2
Asphaltic Material	4–7	5–9	± 0.5
Liquefier	0–1	0–2	± 0.1

HEATING: The combined aggregate shall be heated in a drum-type drier to a moisture content of less than 0.75% at the dry end of the drum. If two or more aggregates are used, they must be pre-mixed before feeding to the drier. The aggregate shall be heated sufficiently that it shall be delivered to the mixer at 225-275°F. The asphaltic material shall be heated sufficiently that it shall be delivered to the mixer at 225-275°F.

WEIGHING: The aggregate scales shall be dial or beam type and sensitive to ½ of 1% of the charge capacity. If of the beam type, a separate beam is required for each fraction of aggregate. The asphalt scale capacity must be sufficient to weigh the maximum requirements for any batch and shall be of the dial or beam type with a tare that can be observed for each weighing. An accuracy of plus or minus 1% of asphaltic material is necessary.

MIXING: The asphaltic material bucket shall be of a type capable of dispersing the material uniformly over the mixer. The minimum allowable batch size is 750 pounds. The mixer shall be of the twin-shaft, pug-mill type and shall be steam jacketed. The distance between moving and fixed parts shall not exceed 1 inch. In loading the mixer, the aggregate shall not cover the top of the mixer teeth when they are in a vertical position. The aggregate shall be mixed dry for 15 seconds, the asphaltic material added and the batch mixed for 45 seconds or such time as is required to uniformly coat the particles.

MIXING WITH LIQUEFIER: If the material is to be transported long distances the Engineer may allow a small percentage of liquefier to be added. This shall be sprayed in at a measured rate. It shall be introduced after 30 seconds of aggregate and asphaltic material mixing, and mixing shall continue for an additional 15 seconds. When using liquefier, it is desirable to have a minimum of 200 mesh material to facilitate evaporation.

TRANSPORTATION OF MATERIAL: The mixture shall be hauled in box trucks of strong design with metal box bottoms. The loads shall be covered with tarpaulins when necessary. The boxes shall be lubricated with just sufficient light oil to prevent the mix adhering to them.

SPREADING: The mixture shall be laid only when the primed grade is dry or free from standing water and when atmospheric conditions are right. No paving shall be carried on when air temperatures are lower than 40°F. All low places in the primed grade shall be brought up to grade with the necessary amount of mixed material. The mixture shall be laid at from 175-250°F. and variations from the temperature specified by the Engineer, shall not exceed 20 degrees. The mixture shall be spread by hand or by an approved type of mechanical paver. When spread by hand the mixture shall be unloaded on a dumping plate outside the area to be covered, and placed by hot shovels and rakes. Oiled tools will not be permitted. The teeth of the rakes shall be at least ½″ longer than the pavement thickness and the spacing shall not be more than 1¾″. Rakers must not walk on the fresh material unless to correct faults and then they must wear clogs. Curbs, joints, manholes and similar structures shall be painted with a thin coat of hot asphalt cement or asphalt dissolved in naphtha at 200°F. At points of contact with curbs, manholes, etc., the pavement shall be finished ¼″ higher than such structures. Joints shall be cut back and painted unless canvas rope joints are used.

ROLLING: The rollers must not pass over unprotected edges unless one side section is being run out to start back on the second side. The rollers shall not weigh less than 10 tons and shall not travel in excess of 3 miles per hour. The rate of rolling shall not exceed 150 square yards per hour per roller from June to September and 100 square yards per hour per roller from September to June, and rolling shall continue until all roller marks are eliminated. Each roller shall operate 6½ hours out of 8 and not more than 1½ hours shall be occupied by cleaning, fires, etc. The final rolling shall require a weight of 200 pounds per inch width of roller wheel. The rolling shall be longitudinal from sides to centre, overlapping each run by 2 feet and varying the lengths of the runs. This shall be followed by cross-rolling with a tandem roller of at least 10 tons. If the width of the pavement permits, roll shall be at right angles. Along curbs, manholes, etc., tampers or proper tools shall be used to give the pavement the proper compaction.

FINISHED SURFACE: The pavement shall conform to line and cross-section and shall be at least 2″ thick. It shall be ±¼″ of the thickness specified by the Engineer. There shall be no variations greater than ⅛″ shown under a 10′ straight-edge. Low or defective spots shall be cut out down to grade and replaced to standard with fresh material. After final compaction the density shall never be less than 94% of the maximum density possible in a mixture of the same proportion having no voids.

SURFACE TREATMENT:

PLANT-MIXED SEAL COAT: As soon as possible after the asphaltic concrete is compacted, while it is still clean, warm

and freshly laid and before traffic has passed over it, it shall be uniformly covered with plant-mix seal coat at a rate of 20-40 pounds per square yard as directed by the Engineer. This shall be spread longitudinally by shovels or rakes. After spreading it shall be rolled with a 10 ton roller.

ALTERNATE SURFACE TREATMENT: SQUEEGEE SEAL COAT: In lieu of plant-mix seal coat, the surface may be covered with a coat of asphalt cement at a temperature from 275-350°F. at a rate of 0.35 gallons per square yard or as directed. The asphalt cement shall be used in such quantity as will cover the surface and fill surface voids. Rubber squeegees shall be used only to correct irregularities in distribution. Immediately after spraying, chips, gravel or a mixture of both shall be spread at a rate of 20-40 pounds per square yard as directed, and rolled. A slight excess of aggregate shall be left on the surface. If necessitated by unfavourable weather the aggregate shall be heated to not more than 300°F. as directed by the Engineer and rolled in at once.

ANALYSIS OF TYPICAL PAVEMENT SAMPLE—
PLANT-MIX DENSE GRADED
BITUMINOUS CONCRETE:

Density	2.39
Stability, 3¾" ring	3700#
Temperature at plant	225°F.
Temperature at road	220°F.
Bitumen variation from formula	-0.1%

Grading

Passing	Held On	Per cent
1¼" round	1¼" round	3.9
¾" round	¾" round	24.2
⅜" round	⅜" round	17.4
4 Mesh	4 Mesh	6.2
8 Mesh	8 Mesh	8.4
14 Mesh	14 Mesh	8.7
28 Mesh	28 Mesh	8.0
48 Mesh	48 Mesh	8.0
100 Mesh	100 Mesh	6.4
200 Mesh	200 Mesh	4.8

Total Mineral Aggregate	96.0
Bitumen	4.0
Water	0.0
Total	100.0

NOTE: The following page shows specifications and an analysis of the asphaltic products generally used by the Dept. of Roads in Quebec.

	Asphalt Primer MC-1		Asphalt Cement 90 M.P.		Asphalt Cement 91/100 Pen.		Carpet Asphalt MC-2		MC-3 Asphalt		Surface Treating Asphalt RC-5	
	Spec.	Sample	Spec.	Sample	Spec.	Sample	Spec.	Sample	Spec.	Sample	Spec.	Sample
Water, % max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Specific Gravity at 60°F., min.	0.975	.975	1.000	1.006	1.000	1.017	—	.960	—	.965	—	.9725
Flash Point (O.C.)°F., min.	80	90	300	490	....	505	80	108	80	138	80	126
Softening Point (B&R) °F.	....	....	85–95	91	....	117	....	....	....	....	....	....
Penetration at 77°F., 100 grs., 5 secs.	....	....	....	....	91–100	94	....	....	....	....	....	....
Penetration at 32°F., 100 grs., 5 secs., min.	....	....	....	....	5+	22	....	....	....	....	....	....
Volatility 325°F., 50 grs., 5 hrs., % loss wt., max.	....	....	2.0	0.4	1.50	0.10	....	....	....	....	....	....
Viscosity—Saybolt Furol												
At 122°F.	15–40	23	....	....	....	....	75–200	165	200–300	....	....	....
At 212°F.	....	....	min. 150	340	....	....	....	....	....	....	50–90	85
Distillation, % by Volume Off												
At 374°F., min.	4	10.25	....	....	....	....	....	3.5	....	1.0	....	8.25
At 437°F., min.	12	19.5	....	....	....	....	4	7.0	3	4.5	1.0	12.25
At 500°F., min.	16	25.0	....	....	....	....	8	16.0	7	10.25	3.0	14.5
At 680°F., max.	50	33.0	....	....	....	....	35	28.0	30	20.5	25.0	16.25
Distillation Residue, % by Weight, min.	55	70.3	....	....	....	....	....	73.5	....	81.6	....	83.8
Softening Point (B&R) °F., min.	100	105	....	....	....	....	....	110	....	110	....	120
Penetration after Distillation or Volatility at 77°F.	100–250	110	....	....	50%+	84	100–250	128	100–250	135	80–120	80
Ductility at 77°F., min. \ After Distillation	100+	150+	*100+	150+	100	150	100	150+	100	150+	100	150+
Ductility at 40°F., min. / & before Volatility	....	....	10+	....	10	12	....	....	....	....	....	....
Solubility in CS_2 or $CHCL_3$, min.	99.5	99.9	99.5	99.9	99.5	99.9	99.5	99.9	99.5	99.9	99.5	99.9
Solubility in CCL_4, min.	99.0	99.9	99.0	99.9	99.0	99.9	99.0	99.9	99.0	99.9	99.0	99.9
Maximum Heating Temperature, °F.	....	....	225	....	....	....	....	....	....	....	....	....

*The Asphalt Cement 90 M.P. when reduced at 480–500°F. to 100 penetration residue, shall have a ductility at 77°F., 5 cms. per minute of not less than 100 cms. The Asphallt Cement 90 M.P. when reduced at 480–500°F. to 100 penetration residue, shall have a ductility at 40°F., 1 cm. per minute of not less than 10 cms.

NOTE:—Ductilities at 77°F. taken at 5 cms. per minute.
Ductilities at 40°F. taken at 1 cm. per minute.

SASKATCHEWAN

Minister—Hon. A. T. Procter

Deputy Minister—
H. R. MacKenzie

Chief Engineer—
W. W. Perrie

TYPE IN GENERAL USE: The type in general use is Plant-Mix Hot Bituminized Gravel Surface Course spread to a width of 24′ (minimum thickness two inches), on a primed, Stabilized Plant-Mix Gravel Base Course. The bituminized gravel surface course shall be given a subsequent Seal Coat.

PREPARATION OF PLANT-MIX STABILIZED BASE COURSE: The stabilized gravel base course shall be 28′ wide, top width, and 6″ thick, feathering off to nothing in the two feet between the edge of the stabilized gravel base and the shoulder of the graded roadway.

ASPHALTIC MATERIAL: The bituminous water-proofing material shall be RC-1 and shall meet the specifications shown on page 77.

COARSE AGGREGATE: The coarse aggregate shall be crushed gravel consisting of fragments of clean, tough, durable rock, free from clay balls and injurious quantities of soft or flaky particles, loam, organic matter or other deleterious material. It shall all pass the 1″ square screen and shall be uniformly graded from coarse to fine to obtain a high density. Sufficient oversize particles shall be crushed to provide a satisfactory grading.

CLAY BINDER: The clay binder shall consist essentially of fine particles of sand, silt and clay containing no particles larger than will pass a 1″ square screen. It shall be free from organic matter or other deleterious material. It shall have a Plasticity Index of 10-30. The clay must be broken down to its individual particle size by a shredder or pulverizer.

SAND FILLER: When the coarse aggregate and clay binder contain a deficient quantity of sand for a properly graded final mix, finely divided sand shall be added. It shall contain no particles larger than will pass a 1″ square screen and shall be free from injurious amounts of organic matter or other deleterious material.

WATER: The water shall be reasonably clean and free from substances which might render it unfit for use.

COMBINED AGGREGATE AND FINISHED WATER-PROOFED STABILIZED SOIL MIXTURE: This shall consist of the graded aggregate and soil binder, supplied individually

or in combination to give the following gradations and requirements:

STABILIZED SOIL MIXTURE SCREEN REQUIREMENTS		
Passing	Per cent	
	Range	Ideal Cumulative
1″ square screen	100	100
4 mesh	60–80	70
10 mesh	45–65	55
40 mesh	20–30	25
100 mesh	12–20	15
200 mesh	8–15	11

The fraction passing a #40 sieve, without the bituminous water-proofing material, shall have a Plasticity Index of 5-10 and a Liquid Limit of not over 30. The fraction passing #40 sieve shall not be less than 40% or greater than 50% of the fraction passing a #10 sieve. The sum of the percentages of material passing a #40 sieve and the Plasticity Index of this fraction shall not exceed 40. The fraction passing a #200 sieve shall not be less than 40% or greater than 50% of the fraction passing a #40 sieve. All tests shall be made in accordance with Standard A.A.S.H.O. Methods.

MIXING, SPREADING, SHAPING, SPRINKLING AND COMPACTING: The stabilized soil material shall contain approximately 1% by weight of RC-1, see page 77, uniformly distributed throughout the soil mixture as a water-proofing agent. The water-proofed, stabilized base course shall be spread by means of an approved bituminous paver. It shall be laid in three courses, each of which shall be 2″ thick when consolidated. Each layer shall be compacted to a minimum dry density of 140# per cubic foot by a pneumatic, rubber-tired roller. Each layer after compaction shall be allowed to become dry throughout before a succeeding layer is placed over it. The final moisture content of the stabilized mixture in each layer just before compaction, shall not be less than the optimum moisture for the mixture and preferably from 1-2% above the optimum, to assist in rapid compaction. Final compaction must occur at the optimum moisture content in order to obtain maximum density. When necessary, water shall be added in such a manner that the stabilized material is brought to the specified moisture content during the compaction and, if required by the Minister, the layer of stabilized material shall be disced or harrowed during the moistening operation to secure a uniform moisture content. No stabilization construc-

tion will be permitted when the temperature is 35°F. and falling.

PRIMING: The surface of the base course shall be swept free of all loose or foreign materials and bituminous priming material of SC-1 type, see page 77, shall be uniformly applied with an approved type distributor at the rate of ¼ gallon per square yard. The primer shall be applied at a temperature of 70-125°F. and only when the area to be primed is dry and when the air temperature is above 50°F. No subsequent operation shall be carried out on the roadway until the primer has been completely absorbed and then, only in such a manner as not to break the primer layer and, in any case, not before a period of 24 hours has elapsed.

ASPHALTIC MATERIAL: The asphaltic material used in the hot-mix bituminized gravel mixture shall be of SC-5 type, see page 77.

MINERAL AGGREGATE: The mineral aggregate for the plant-mix hot bituminized gravel surface course shall consist of hard, clean, crushed gravel and natural sand, and shall not contain any clay, loam, stripping or other forms of material. It shall meet the following screen requirements:

MINERAL AGGREGATE FOR BITUMINIZED GRAVEL

Passing	Per cent	
	Range	Ideal Cumulative
¾″ square screen	100	100
4 mesh	40–70	53
10 mesh	25–50	38
40 mesh	10–30	20
200 mesh	1–8	3

PLANT-MIX HOT BITUMINIZED GRAVEL MIXTURE: The mineral aggregate shall be pre-heated to a minimum temperature of 150°F. in an approved type drier before being placed in the mixer. Overheating the aggregate will not be permitted. Samples of the aggregate taken immediately prior to mixing shall contain not more than 1% of moisture. The SC-5 bituminous binder shall be delivered to the mixing plant and stored at a temperature not exceeding 275°F. Local overheating will not be permitted. The mixing plant shall be equipped with facilities for separating the mineral aggregate into at least two sizes which shall be stored in separate bins, one containing that portion of the material retained on a ¼″ square screen and

the other containing that portion of the material passing a ¼" square screen. Only rotary shakers for vibrating screens shall be allowed. The two sizes of aggregate and asphalt shall be carefully weighed and combined in proper proportions as directed by the Minister.

MIXING: Mixing operations must be carried out in batches. The bituminous binder shall be heated to 175-235°F. before being introduced into the mixer. The temperature of both aggregate and bituminous binder shall be maintained at not less than 170°F. until mixing is completed. The heated aggregate shall be deposited in the mixer first and the heated bituminous binder added. A pug-mill mixer of approved design and capacity, equipped with an approved timing device shall be used. Mixing shall continue until all parts of the mineral aggregate are uniformly coated—at least 45 seconds. Approximately 4 pounds of bituminous binder to 100 pounds of the aggregate shall be used, which may be varied between 3½-5% as directed by the Minister. The amount of bituminous binder shall be determined from time to time according to mechanical analyses and no variation from the formula will be permitted. The plant shall not operate when the air temperature is 45°F. and falling.

SPREADING: The bituminous mixture shall be spread by means of a bituminous paver in one layer to a depth sufficient to produce a compacted mat of the thickness specified. Spreading shall commence at the point on the project farthest from the plant and proceed toward the plant, unless otherwise permitted by the Minister. All material shall be spread while still warm. The placing of the mixture shall be carried out only when weather conditions are favourable and at an air temperature of at least 50°F. and only when the prepared base is moisture free.

ROLLING: Compaction shall be accomplished by means of an approved, tandem type, self-propelled, smooth steel-tired roller, having adjustable rolling pressure. The maximum weight shall be 250 pounds per inch width of roller.

FINISHED SURFACE: The finished surface shall be perfectly smooth, uniform and free from depressions exceeding ⅜" as measured with a 10' straight-edge paralleling the centre line of the roadway.

SEAL COAT

MINERAL AGGREGATE: The aggregate used for cover shall be composed of hard, durable material with a high resistance to abrasion. It shall not contain more than 3% of moisture when applied and shall conform in size to the following screen requirements:

COVER AGGREGATE SCREEN REQUIREMENTS	
Passing	Per cent
½″ square screen	100
4 mesh	25–55
8 mesh	0–5

CONSTRUCTION: The bituminous material, RC-3 type, see page 77, shall be uniformly sprayed in one application with a distributor of approved type at a rate of ¼ gallon per square yard at a temperature of 70-125°F. as directed by the Minister. Application shall be made only when the air is dry and when the air temperature is above 50°F. After the bituminous material has attained the stage of tackiness desired by the Minister, the cover aggregate shall be uniformly spread over the prepared surface at a rate of 25 pounds per square yard, by an approved mechanical spreader. Immediately after the cover aggregate has been spread, it shall be rolled with an approved pneumatic, rubber-tired roller. The cover aggregate shall be maintained by the contractor for a period of three days after being spread, by redistributing the loose cover aggregate material by some method of brooming.

STANDARDS IN NEW CONSTRUCTION

CROSS-SECTION APPLIED TO GRADING WORK:

Top width of graded roadway ..... 32′
Crown ..... 6″

Roadway slopes 4 to 1 when centre line elevation is less than 5.5′ above the toe of the slope.

Bottom of ditches—fall of 6″ per 20′ away from the centre line of the roadway.

Back slope of ditches 4 to 1.

For embankments the difference in elevation between the centre line of the roadway and the toe of the slope of the roadway shall not be less than 4′. Embankments shall be constructed in layers not exceeding 8″ in depth for the full width of the embankment. If necessary, water shall be added to ensure at least 90% of the maximum density as determined by standard compaction tests. Material containing excess moisture shall be allowed to dry.

In cuts the difference in elevation between the centre line of the roadway and the toe of the slope of the roadway shall not be less than 3′.

Specifications and Tests — ASPHALTIC MATERIALS — Saskatchewan

	SC-1 PRIME COAT		RC-1 STABILIZATION		RC-3 SEAL COAT		SC-5 PLANT MIX HOT		MC-1 PRIME COAT	
	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample	Specification	Sample
Water % max.	0.0	....	0.0	....	0.0	....	0.0	....	....	....
Specific Gravity at 60°F	....	....	....	1.016	....	1.022	....	....	....	0.956
Flash Point (O.C.) °F, min.	150	....	80	85	80	95	350	375	....	80
Softening Point (B&R) °F.	....	....	....	....	....	....	80–90	86	....	....
Viscosity—Saybolt Furol										
At 122°F.	30–60	....	60–70	65	200–300	275	....	....	....	17
At 212°F.	....	....	....	....	....	....	....	....	....	....
Distillation, % by Volume Off										
At 374°F., min.	....	....	6	10	....	6.5	....	....	....	9.5
At 437°F., min.	....	....	14	14	10	10.0	....	....	....	16.5
At 500°F., min.	....	....	18	18	....	13.0	0	....	....	25.0
At 600°F., min.	....	....	....	20	20	16.0	0	....	....	32.5
At 680°F., max.	35	....	40	22	35	17.5	2	0	....	34.5
Distillation Residue, % by Weight min.	....	....	....	83.9	....	89.0	....	100	....	68
Softening Point (B&R) °F., (on Res.)	....	....	....	....	....	....	....	....	....	....
Penetration at 77°F.,100 grs.,5 sec.(onRes.)	....	....	60–160	82	120–180	86	150 (Min.)	....	....	197
Float Test at 122°F. (on Res.)	....	....	....	....	....	....	....	127	....	....
Ductility at 77°F., min., (on Res.)	100*	....	100	110+	100*	110+	100*	110+	....	110+
Ductility at 77°F., min,, (on Res.)	....	....	....	....	100†	....	100†	110+	....	....
Solubility in CS_2, % min.	99.5	....	99.5	99.63	99.5	99.69	99.0	99.74	....	99.79

*Ductility Test is made on residue reduced to 100 penetration.
†Ductility Test is made on residue reduced to 50 penetration.

CITY OF TORONTO

Commissioner of Works—
R. C. HARRIS

Roadway Engineer—
L. B. ALLAN

TYPE IN GENERAL USE: The types in general use are Sheet Asphalt wearing surface 1½″ thick or Asphaltic Concrete wearing surface 1½″ thick, laid upon a Binder Course 1½″ thick which is laid on a Portland Cement Concrete Base of variable thickness.

ASPHALTIC MATERIAL: The asphaltic material shall be asphalt cement conforming to the specifications on page 83.

STONE: The stone used in the binder course shall be ¾″ trap and shall meet the following test. A sample shall be taken, washed and carefully screened to the following grading:

BINDER COURSE STONE TEST GRADING	
Held On	Per cent
1½″ screen	0
1¼″ screen	3.0
1″ screen	27.0
¾″ screen	50.0
½″ screen	20.0

3,000 grams of this graded stone aggregate (having a fineness modulus of 710.0) shall be placed in a 6″ diameter cast iron cylinder and a load of 300 pounds per square inch gradually applied with a loose fitting plunger. The product shall then be screened on the following sieves—1″, ¾″, ½″, 4 mesh, 8 mesh, 20 mesh, 50 mesh, 100 mesh. The resulting modulus calculated on the sum of the percentages coarser than each sieve, must show a value of not lower than 695 for the stone to be accepted.

SAND: The sand shall be hard grained, clean and moderately sharp and shall not contain more than 1% of clay or loam. It shall approximate the following screen requirements:

SAND SCREEN REQUIREMENTS		
Passing	Held On	Per cent
8 mesh	30 mesh	20
30 mesh	50 mesh	27
50 mesh	80 mesh	30
80 mesh	100 mesh	15
100 mesh	200 mesh	7
200 mesh		1

MINERAL DUST: The mineral dust shall be clean, dry, finely pulverized limestone or other mineral dust approved by the Commissioner of Works. At least 85% shall pass a 200 mesh sieve.

BINDER COURSE: The combined aggregate for the binder course shall conform to the following approximate proportions by weight:

COMBINED AGGREGATE BINDER COURSE	
Fraction	Per cent
Stone	82
Sand	13
Asphalt Cement	5

MIXING, SPREADING AND ROLLING: The stone and sand shall be heated to a temperature of 300-350°F. and mixed with the asphalt cement at 250°F. in a standard asphalt plant mixer, to produce a thoroughly homogeneous mass, with all the mineral aggregate covered with asphalt cement. The binder course shall be laid hot upon the concrete base to such thickness that, after compaction by a roller weighing at least 5 tons, it shall be not less than 1½" thick. It shall be rolled until cold and the finished surface shall be parallel to the proposed surface of the pavement. A proper bond shall be shown among the particles and to the foundation.

SHEET ASPHALT WEARING SURFACE: The materials making up the sheet asphalt shall be mixed in the following approximate proportions by weight:

COMBINED AGGREGATE SHEET ASPHALT	
Fraction	Per cent
Sand	67–85
Mineral Dust	5–18
Asphalt Cement	10–15

MIXING, SPREADING, ROLLING AND FINISHED SURFACE: The materials shall be mixed in such proportions by weight as will produce the densest mixture possible and practicable. The sand and asphalt cement shall be heated separately to approximately 325°F. The sand, dust and asphalt cement, composing the charge for any mixture shall be weighed separately. The mineral filler shall be added to the hot sand in

a standard type of asphalt plant mixer. The asphalt cement shall be added after the sand and dust are thoroughly mixed. The whole shall then be mixed to produce a homogeneous mass, with all the mineral aggregate completely covered with asphalt cement. The surface mixture shall arrive at the street at a temperature of 250-350°F. Material below 250°F. shall be rejected. The unloaded material must be promptly shoveled into place and spread with rakes. All lumps must be broken up and the whole surface uniformly spread to ensure a depth of at least 1½″ when compacted. Before placing the mixture all contact surfaces such as joints, gutters, curbs, manhole tops, etc., must be painted with hot asphalt cement. Compaction shall be obtained by a roller weighing not less than 10 tons and having wheels at least 24″ wide. After rolling, hydraulic cement or pulverized limestone shall be swept over the surface. Final rolling shall be carried out by a tandem roller of not less than 5 tons in weight. The rolling shall be carried out diagonally and longitudinally and, if the pavement is of sufficient width, at right angles to the line of the street. The surface shall be rolled until it is uniformly compacted and no impression is made thereon by the roller. Hot tampers shall be used in places where it is impossible to compact by rolling. The finished surface shall be true to line and grade. The surface at the gutter shall be finished ⅓″ to ¼″ higher than the edge of same.

ASPHALTIC CONCRETE WEARING COURSE: Another type of wearing course is asphaltic concrete of the following specifications, laid upon the standard type concrete base and binder course construction. The stone shall be of trap specification with 100% passing the ½″ sieve. The materials making up the mixture shall be mixed in the following approximate proportions by weight:

COMBINED AGGREGATE ASPHALTIC CONCRETE	
Fraction	Per cent
Stone (trap)	48–65
Sand	25–36
Mineral Dust	4–6
Asphalt Cement	6–10

MIXING, SPREADING, ROLLING AND FINISHED SURFACE: The stone and sand shall be heated to 300-400°F. and, after being thoroughly mixed with the mineral dust in a standard type asphalt plant mixer, shall be further mixed with the asphalt cement, heated to 250°F., until a homogeneous mass is produced. The stone, sand, dust and asphalt cement shall be weighed into the batch separately. Mixing shall be

continued until all the mineral aggregate is uniformly coated with the aspalt cement. The mixture shall arrive at the street at 225-350°F. and shall be spread with rakes in the manner specified for sheet asphalt. Each course shall be at least 1½" thick and shall be laid and rolled separately while hot and plastic. Rolling shall be continued both longitudinally and diagonally, and if possible at right angles to the line of the street until no impression is made on the asphaltic concrete by the roller. No more of the binder course shall be laid at one time than can be covered with surface course in the same day. The finished surface shall be even and true without waves or depressions. After rolling a thin coat of asphalt cement shall be spread over the entire surface and while this is still hot it shall be completely and evenly covered with clean, sharp, hot sand and heavy rolling continued until ultimate compression is obtained. Sometimes this procedure is not followed and the surface is left open.

CITY OF TORONTO

TYPICAL ANALYSIS OF SAND AS USED IN SHEET ASPHALT AND A SAMPLE OF MINERAL FILLER

GRADING	SAND	DUST
Held On	Per cent.	Per cent.
½″ screen		
¼″ screen		
8 mesh		
10 mesh	4.0	
20 mesh	14.0	
30 mesh	12.0	
40 mesh	8.0	
50 mesh	19.0	0.0
80 mesh	21.0	0.1
100 mesh	17.0	0.1
200 mesh	4.5	5.2
Passing 200 mesh	0.5	94.6
Total	100.0	100.0
Percentage voids	36.0	
Dust by elutriation		88.0
Bitumen used in sheet mix	10.16	

FORMULA USED FOR ASPHALTIC CONCRETE MIXTURE (Mt. Pleasant Rd.)

Trap Rock	58.0
Sand	29.8
Dust	6.0
Asphalt Cement	6.2
Total	100.0

Specifications and Tests — ASPHALTIC MATERIALS — City of Toronto

	ASPHALT FILLER*		ASPHALT CEMENT†		ASPHALT CEMENT‡	
	Specification	Test	Specification	Test	Specification	Test
Water, % max.	0.0	0.0	0.0	0.0	0.0	0.0
Flash Point, (O.C.) °F., min.	392	510	347	585	347	530
Softening Point (B&R) °F.	149–230	171	....	....	....	....
Penetration 32°F., 200 grs., 1 min., min.	10	15	....	....	....	....
Penetration 77°F., 100 grs., 5 sec.	30–50	35	100–120	116	50–60	51
Penetration 100°F., 100 grs., 5 sec.	....	75	....	....	....	141
Penetration 115°F., 100 grs., 5 sec., max.	110	....	....	....	....	....
Susceptibility Factor (Pen. 100°F.. Pen. 77°F.) max.	....	....	....	....	2.8	2.74
Volatility 325°F., 50 grs., 5 hrs., % loss wt., max.	1.0	0.11	2.0	0.17	2.0	0.1
Penetration at 77°F. after heating as % Pen. 77°F. before heating, min.	60.0	87.5	60.0	79.2	60.0	80.7
Ductility at 77°F., 5 cm./sec., min.	3	4	30	110+	50	58
Solubility in $CC/_4$, % min.	99.0	99.9	99.0	99.9	99.0	99.9

*Asphalt Filler for brick pavements.
†Asphalt Cement for hot application.
‡Asphalt Cement for Plant Mix Binder Course, Sheet Asphalt and Asphaltic Concrete.

CHAPTER III.

INFORMATION RELATIVE TO THE APPLICATION, HEATING AND GAUGING OF ASPHALTIC MATERIALS

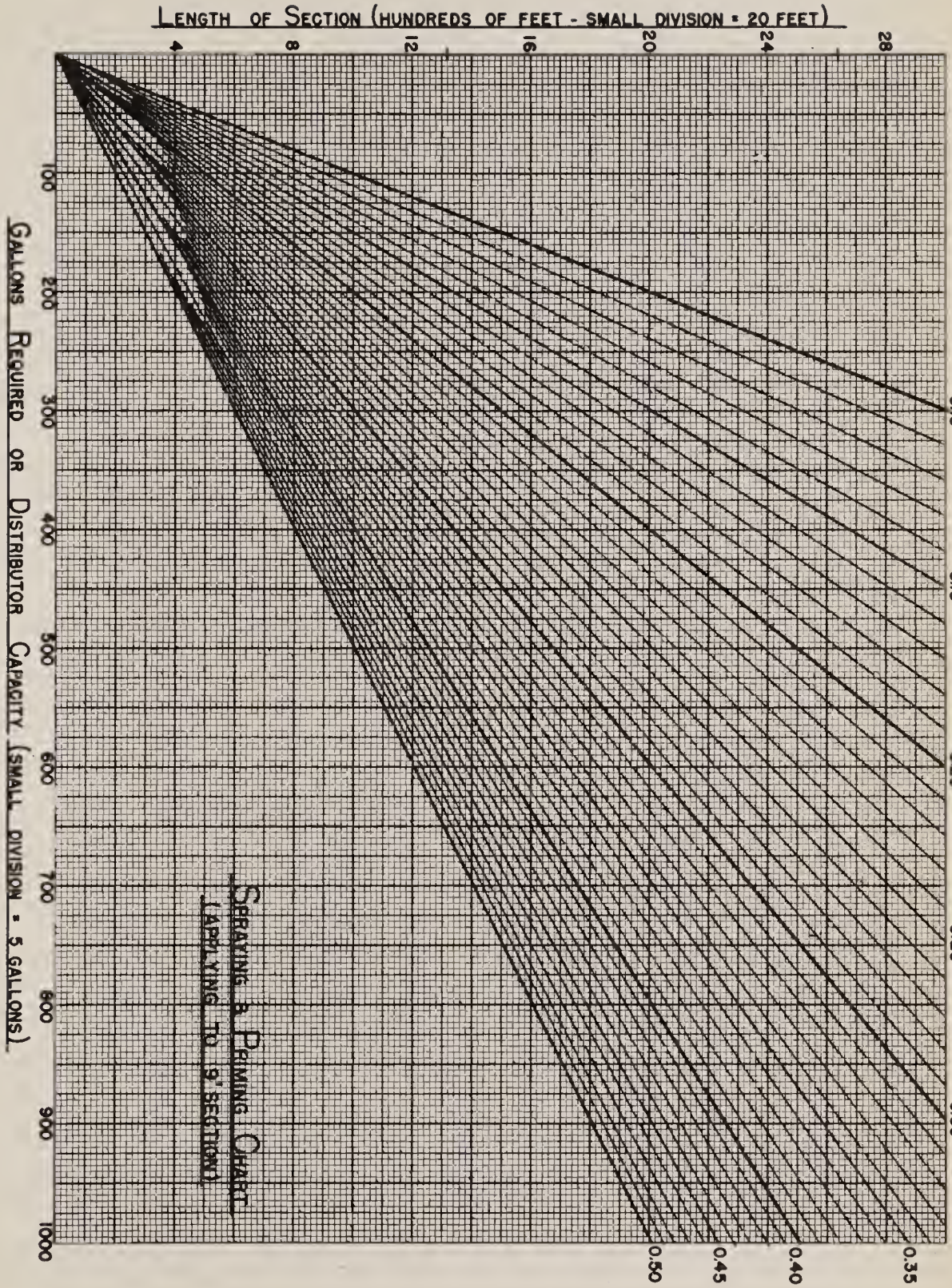
(a) SPRAYING OR PRIMING QUANTITY CHARTS

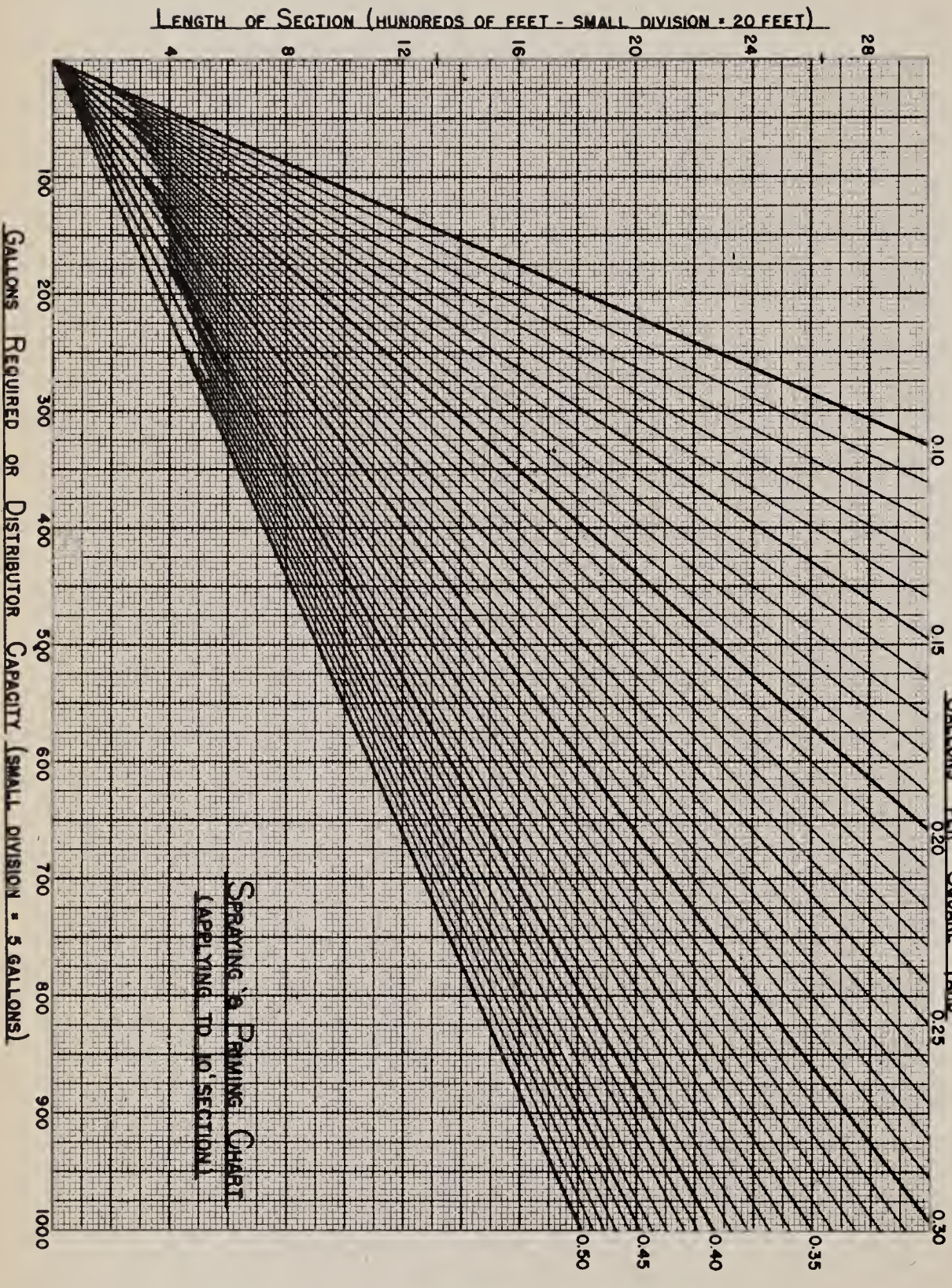
The following charts may be used instead of calculation with any type of spraying, priming, surface treatment or similar operation. The six charts cover sections of 9′, 10′, 11′, 12′, 13′ and 14′ widths. Using simple multiples, figures for other widths may be readily obtained.

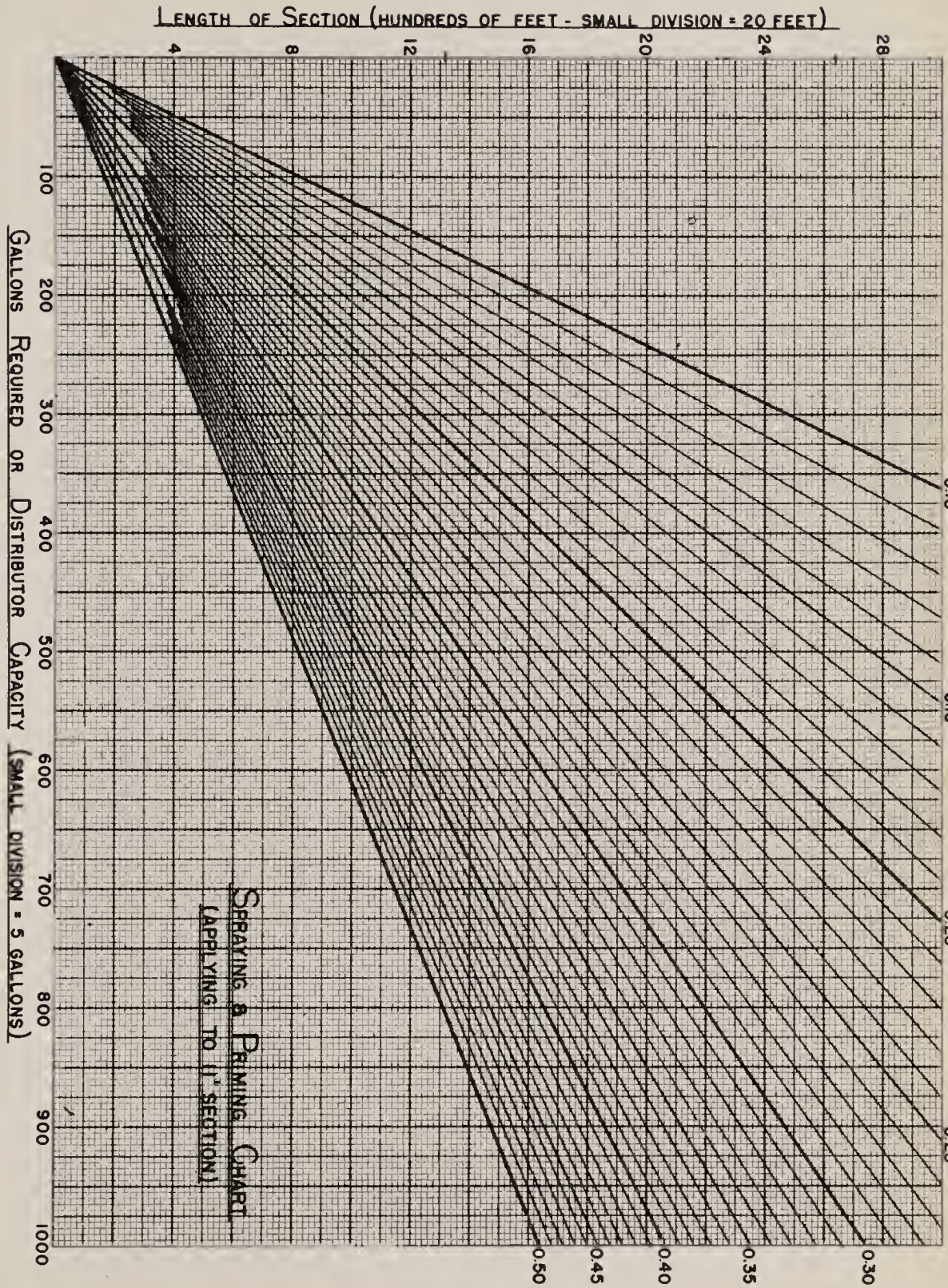
The *lineal feet* which a distributor load of known quantity should carry may be graphically obtained from the ordinate using the chart applicable for the width sprayed, depending on such variables as a specified rate of application.

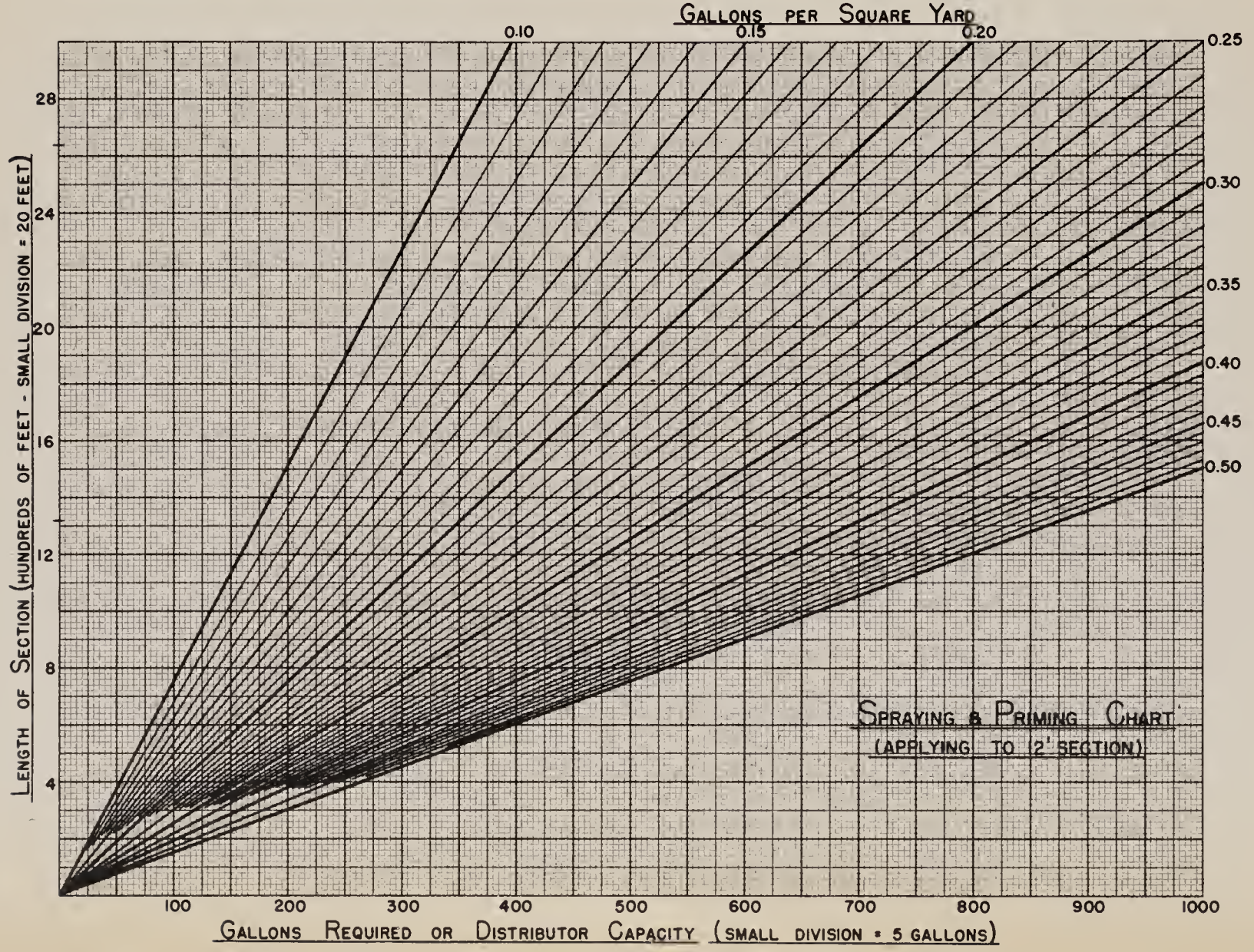
Inversely, the *rate of application* may be graphically obtained from a figure for the lineal feet as sprayed by a known quantity from the distributor, using the chart applicable for the width sprayed.

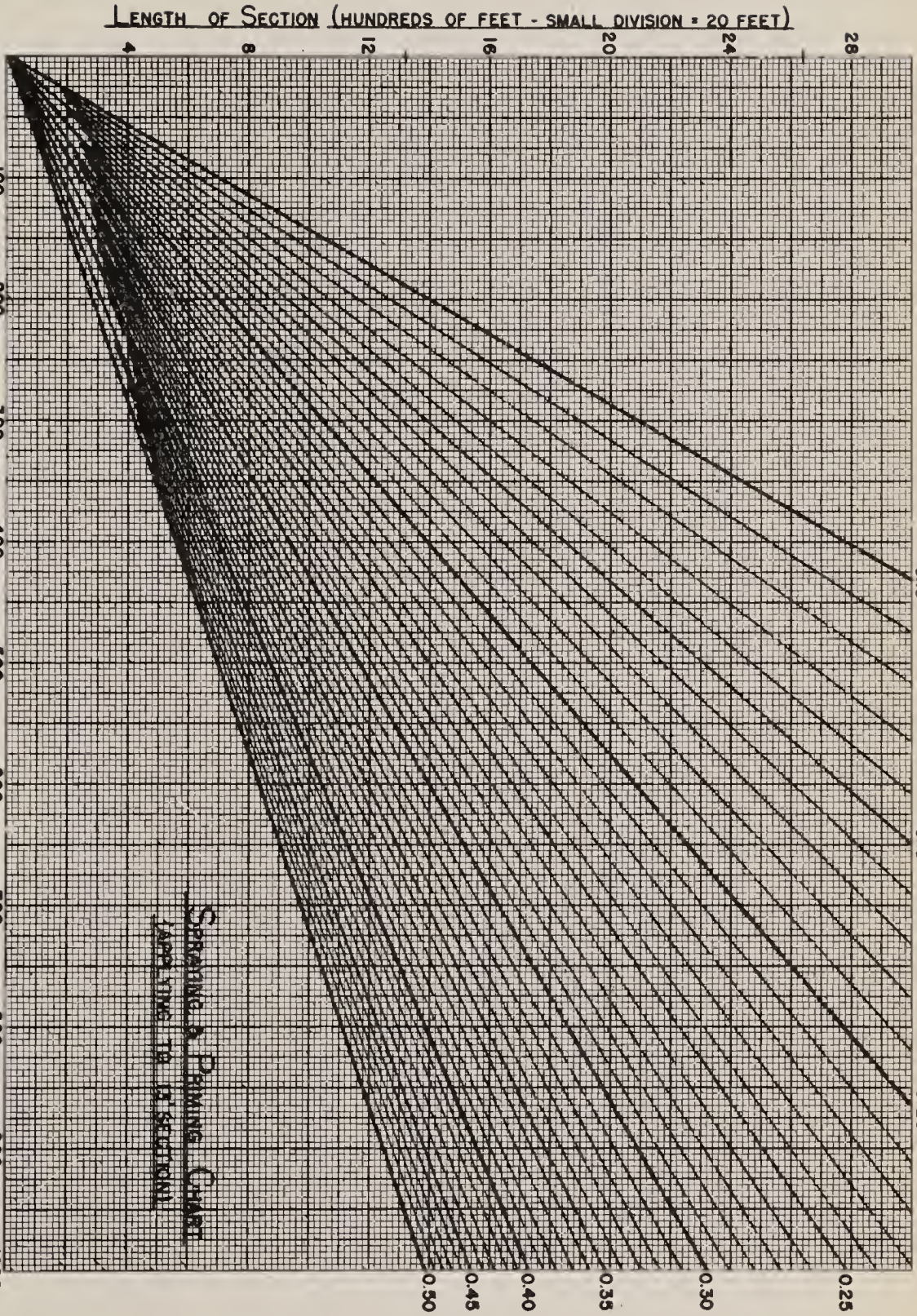
The *quantity of material required* for any number of lineal feet of a specified width, at a specified rate of application, may be obtained by following the vertical scale to the intersection of the line representing the spread per square yard and reading the corresponding figure on the horizontal scale.

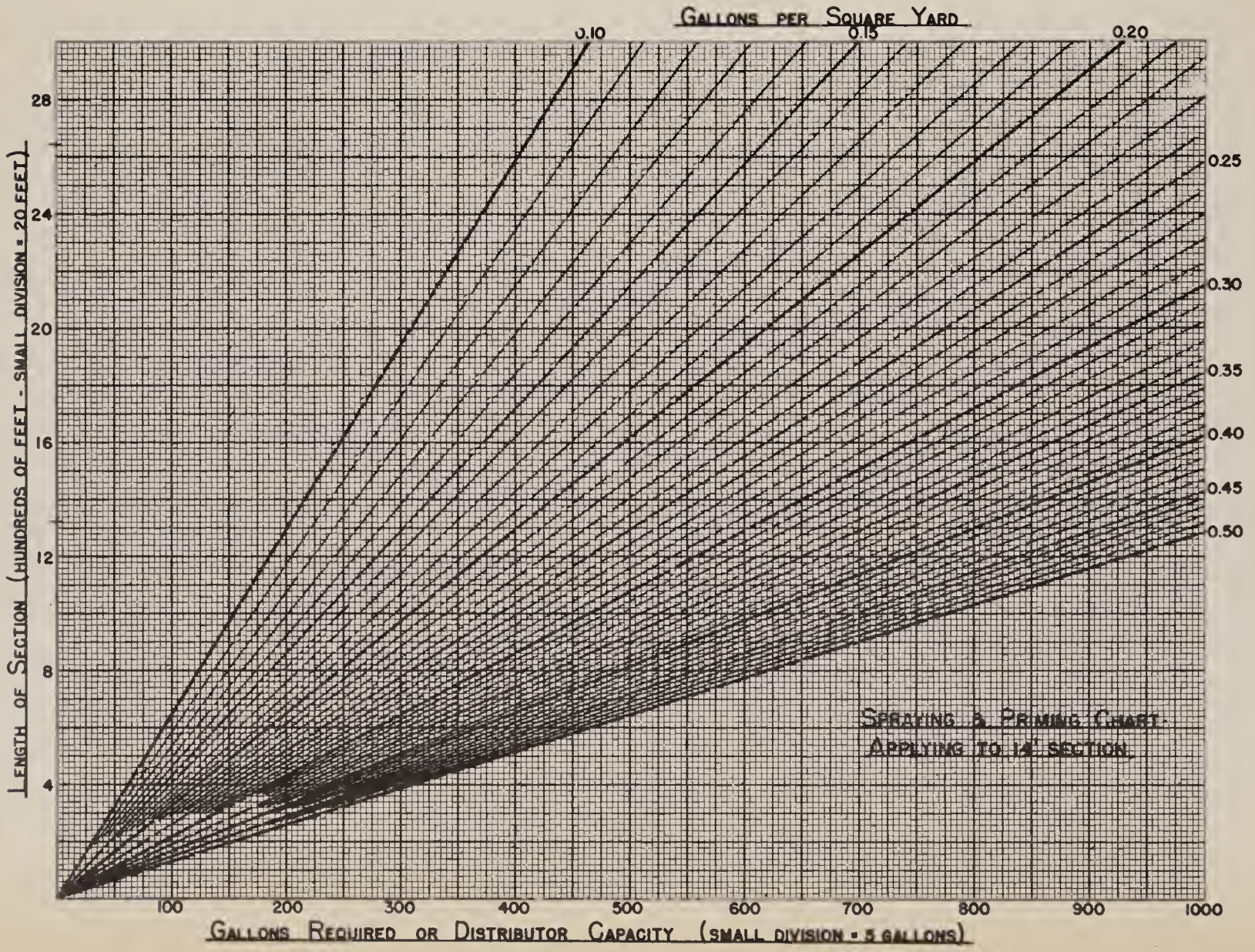

LENGTH OF SECTION (HUNDREDS OF FEET - SMALL DIVISION = 20 FEET)
4
8
12
16
20
24
28
GALLONS REQUIRED OR DISTRIBUTOR CAPACITY (SMALL DIVISION = 5 GALLONS)
100
200
300
400
500
600
700
800
900
1000
GALLONS PER SQUARE YARD
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
SPRAYING & PRIMING CHART
(APPLYING TO 9' SECTION)


LENGTH OF SECTION (HUNDREDS OF FEET - SMALL DIVISION = 20 FEET)
4
8
12
16
20
24
28
100
200
300
400
500
600
700
800
900
1000
GALLONS PER SQUARE YARD
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
SPRAYING & PRIMING CHART
(APPLYING TO 30' SECTION)
GALLONS REQUIRED OR DISTRIBUTOR CAPACITY (SMALL DIVISION = 5 GALLONS)


LENGTH OF SECTION (HUNDREDS OF FEET - SMALL DIVISION = 20 FEET)
4
8
12
16
20
24
28
GALLONS REQUIRED OR DISTRIBUTOR CAPACITY (SMALL DIVISION = 5 GALLONS)
100
200
300
400
500
600
700
800
900
1000
GALLONS PER SQUARE YARD
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
SPRAYING & PRIMING CHART
(APPLYING TO 11' SECTION)


GALLONS PER SQUARE YARD
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
LENGTH OF SECTION (HUNDREDS OF FEET - SMALL DIVISION = 20 FEET)
4
8
12
16
20
24
28
100
200
300
400
500
600
700
800
900
1000
GALLONS REQUIRED OR DISTRIBUTOR CAPACITY (SMALL DIVISION = 5 GALLONS)
SPRAYING & PRIMING CHART
(APPLYING TO 12' SECTION)


LENGTH OF SECTION (HUNDREDS OF FEET - SMALL DIVISION = 20 FEET)
4
8
12
16
20
24
28
GALLONS PER SQUARE YARD
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
GALLONS REQUIRED OR DISTRIBUTOR CAPACITY (SMALL DIVISION = 5 GALLONS)
100
200
300
400
500
600
700
800
900
1000
SPRAYING & PRIMING CHART
APPLYING TO 12' SECTION


GALLONS PER SQUARE YARD
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
LENGTH OF SECTION (HUNDREDS OF FEET - SMALL DIVISION = 20 FEET)
28
24
20
16
12
8
4
100
200
300
400
500
600
700
800
900
1000
GALLONS REQUIRED OR DISTRIBUTOR CAPACITY (SMALL DIVISION = 5 GALLONS)
SPRAYING & PRIMING CHART -
APPLYING TO 14' SECTION.

(b) SAMPLING ASPHALTIC PETROLEUM PRODUCTS

PURPOSE: Samples are taken in order to have convenient quantities of the product under consideration to represent the whole amount of material. These samples are taken to show if there are variations of qualities or the average grade of material.

Sampling of some materials is governed by fixed rules, although there is no substitute for skill, judgement and experience.

GRADES OF MATERIAL: The asphalts to be sampled will be liquid, semi-solid, or solid. Consequently different methods apply to various grades.

CONTAINERS: For the first two classes of material, a leakproof tight container is necessary. The solid material may be stored in any reasonably tight non-adhesive box. Containers for liquids should have a capacity of about one quart and solid samples should weigh two to three pounds.

It is desirable to have new containers if possible, for samples. In any case, containers should be perfectly clean and dry, and of material which will not contaminate the sample.

DISPOSITION OF SAMPLES: Two duplicate samples should be taken whenever possible. One sample forwarded for laboratory tests and a sample preserved until tests are completed with approved results.

TYPES OF SAMPLING: There are many types of samples—i.e., grab samples, average samples, all-level samples, top, middle, bottom composite samples, continuous and borings samples.

Of these types, probably the most suitable for use with liquid asphaltic materials is the all-level sample.

SAMPLING LIQUID ASPHALTS: In sampling tank cars or tank trucks of liquid asphalts by the all-level method, a weighted container holding the sample tin, suspended by a suitable chain, with an opening about three-quarters of an inch in diameter, is lowered into the car of asphalt and rapidly dropped to the bottom. The rapidity of filling may be judged by the air bubbles rising to the surface. The container is raised gradually, but more quickly when near the bottom than the top. The rate of rise should be such that the container will be full when it breaks the surface at the top. If the container is not full, the operation may be repeated. As mentioned previously, it is desirable to have new inspected screw-top containers for obtaining samples. The sample should preferably be

delivered to the laboratory in the same container which was used for sampling the tank car or truck.

Before the sample is removed from the tank, it should be allowed to drain, then if the container is entirely full, a small amount poured from the containers to allow for liquid expansion. The stopper should be placed on the container immediately, and the container may be wiped clean with a cloth.

Unless absolutely necessary, samples should not be taken when rain is falling. Any sampling done during a rain-storm should be protected by means of a waterproof covering over the car or truck. The sample container should have the stopper firmly in position before exposing to any rain.

Identification of samples should be made by means of a cardboard tag, or other suitable type of tag, tied with a string, or wire, to the handle or screw top of the sample container. The information should include initials and number of car, date of arrival, date of sampling, place of sampling and name of contractor.

SAMPLING SOLID ASPHALTS: When normally solid asphalts can be conveniently sampled by melting and taking liquid samples, this should be done. The procedure is similar to that of liquid samples. Samples of solid asphalts from drums may be taken by chipping or boring with an augur. Samples should be taken from several locations, i.e.—centre, half-way towards perimeter on left side, and similarly on right side. If any difference in appearance is noted in samples from these locations, they should be separately preserved. The samples should be mixed thoroughly and divided into two equal portions. One portion sent to the interested laboratory, and a second portion reserved. Identification should be made as mentioned under liquid samples.

The operation of sampling should be given careful thought, because of the variations which occur in different cases. The attention given to the procedure will usually return manyfold the time and effort expended.

(c) INSTRUCTIONS FOR HANDLING TANK CARS CHECKING AND UNLOADING:

Do not start unloading operations until you know that the car is for you and what the contents are.

In the event of missing or broken dome or outlet pipe seals, leakage, loss or damage to contents or car, have the railroad agent make an inspection, verifying the measurement and

temperature of contents and seal numbers. Full particulars must be shown on a signed copy of the freight bill. Wire or telephone us for authority to unload. If these instructions are not followed, no claim for shortage can be allowed.

To check the gallonage contents of a tank car measurement and temperature of the material should be taken, one immediately after the other.

MEASUREMENT: The gallonage contents of a tank car is figured from the capacity of the tank not including the dome. This capacity is clearly stencilled on the car. If the tank is not level full add to capacity "innage in dome" which is measured from the top of the inside top shell of the tank to the surface of the material, or deduct from the capacity "outage in tank" which is measured from the bottom of the inside top shell of the tank to the surface of the material. Gauge sheets referring to the car or type of car show the representative gallons for "outage in tank" or gallonage per inch for "innage in dome". (See page 97.)

TEMPERATURE: Check temperature by taking three readings—one about a foot from the bottom, one about a foot below the top shell of the tank and the third about the centre of the tank. Average these by taking eight times the centre temperature plus bottom and top temperatures and dividing by ten. A conversion factor is obtained by referring to the temperature correction table for that particular material. (See pages 98 and 99.)

UNLOADING THROUGH THE BOTTOM OUTLET:

(a) Make certain the valves are properly seated by (if spring type valve) moving red handle in dome back and forth a few times. The valve is closed when the handle is in near contact with the valve rod bracket. If the valve is positive type, rotate the valve rod wheel. The valve is closed when wheel is tight when turned to the right.

(b) Slowly unscrew the valve cap with a suitable wrench until any accumulated liquid escapes from the outlet chamber, but be certain sufficient threads are left engaged to hold valve cap and prevent loss of contents should the valve not be properly seated. When leakage stops remove cap. If leakage continues endeavour to reseat outlet valve. If this fails, screw cap on tightly and unload through dome. (Note: Spring type outlet valves may not be properly closed if the nut on top of handle is too tight. Loosen nut with rod in open position, then turn handle to closed position. Tighten nut after unloading connection is attached.)

(c) If valve cap sticks, tap lightly upward with mallet or wooden plug.

(d) Attach unloading connection securely to outlet nozzle.

(e) Check all connections and valves from car to storage tank.

(f) Raise outlet valve.

(g) Do not use a flame under frozen outlet valves. Use steam or apply burlap saturated with boiling water, wrapped in dry burlap or heavy paper.

USE OF HEATER COILS:

All insulated tank cars have two heater units, each with separate feed and outlet. If one unit is leaking, this may be isolated by turning the three-way stop-cocks (See "L" in illustration).

(a) Remove dome cover.

(b) Attach globe valve to coil outlets, opening valve full.

(c) Connect steam line to coil inlet, steam slowly for ten minutes to heat pipes, then turn on full. (Note: Quick application of high pressure steam may rupture heater pipes).

(d) When steam shows at outlet adjust valve to take care of condensation.

(e) To retain heat while steaming, with "Screw Type" replace dome cover loose so that vent holes are exposed, with "Bolted Type" replace dome cover with a small wooden block between cover and dome ring seat. Make certain wood does not fall into tank.

(f) When unloaded blow out heater pipes to remove condensation.

(g) Leave inlet and outlet heater pipe caps hanging by their safety chains to permit further drainage.

SUPERVISION OF UNLOADING:

Unloading operations must be under constant supervision. If pump fails or other emergency delays unloading, the bottom outlet valve must be closed, unloading connections taken off, the outlet cap and the dome cover replaced and tightened.

INSTRUCTIONS FOR AFTER UNLOADING:

Withdraw connections immediately unloading is completed and be sure that:

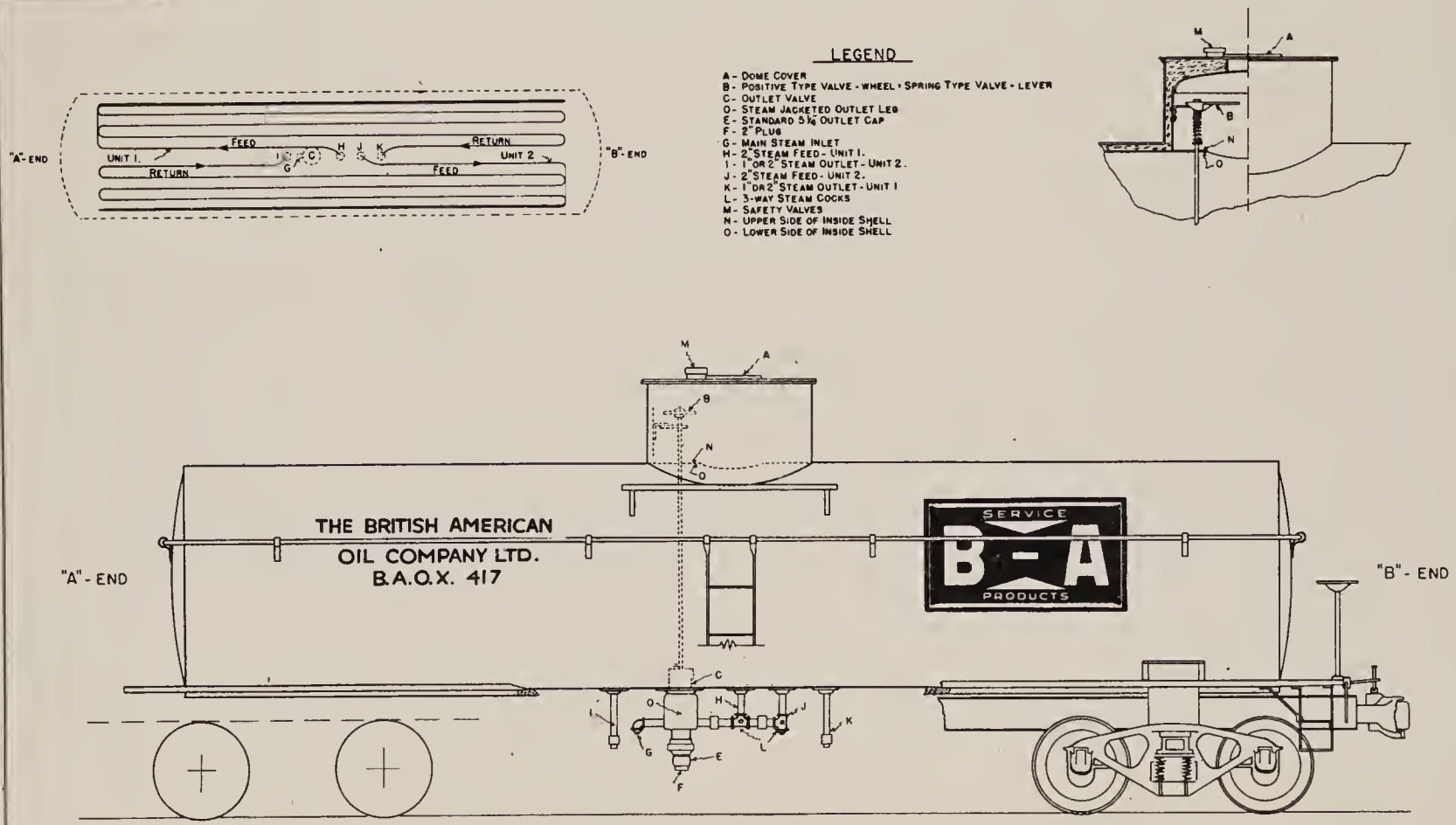
(a) Car is completely unloaded.

(b) All gaskets, outlet valve caps and dome cover are replaced and *securely* fastened by the use of a bar or wrench having a handle at least 48 inches long.

(c) All shipping cards, rags, old seals, globe valves, etc., are removed from car, except railroad defect cards.

(d) Inflammable placards *must* be removed by the party unloading the tank car. Accomplish this by (1) complete detachment of paper placards pasted or tacked on the car (2) reverse placards if the car is equipped with metal placard holders.

(e) Have railroad agent sign empty shipping instructions immediately and make certain car moves on first available train.


LEGEND
A - Dome Cover
B - Positive Type Valve - Wheel - Spring Type Valve - Lever
C - Outlet Valve
D - Steam Jacketed Outlet Leg
E - Standard 5½ Outlet Cap
F - 2" Plug
G - Main Steam Inlet
H - 2" Steam Feed - Unit 1.
I - 1" or 2" Steam Outlet - Unit 2.
J - 2" Steam Feed - Unit 2.
K - 1" or 2" Steam Outlet - Unit 1
L - 3-way Steam Cocks
M - Safety Valves
N - Upper Side of Inside Shell
O - Lower Side of Inside Shell
"A" - END
"B" - END
UNIT 1.
UNIT 2
FEED
RETURN
RETURN
FEED
THE BRITISH AMERICAN
OIL COMPANY LTD.
B.A.O.X. 417
SERVICE
B - A
PRODUCTS

(d) DIAGRAM OF A TYPICAL B-A INSULATED TANK CAR

(e) GAUGE TABLES

AVERAGE OUTAGE TABLES FOR B-A TANK CARS

NOTE: Dry reading is in imperial gallons from inside top shell of tank excluding dome.

DRY READING	CAPACITY OF CAR IN GALLONS		
	5000	6700	8300
1″	19	28	24
2″	39	63	64
3″	72	105	109
4″	113	152	159
5″	158	205	210
6″	205	262	266
7″	255	323	330
8″	338	388	396
9″	364	456	466
10″	425	527	542
11″	487	600	621
12″	553	676	700
13″	622	755	782
14″	690	838	872
15″	759	924	962
16″	831	1011	1055
17″	906	1100	1152
18″	982	1191	1250
19″	1060	1284	1344
20″	1139	1379	1442
21″	1223	1474	1546
22″	1307	1571	1651
23″	1389	1670	1758
24″	1473	1771	1867
25″	1560	1873	1976

AVERAGE INNAGE TABLES FOR DOMES

NOTE: Wet reading is in imperial gallons from top of shell to level of material in dome.

WET READING	CAPACITY OF CAR IN GALLONS		
	5000	6700	8300
Per in. in dome . . .	6.5	8.2	9.6

(f) CONVERSION TABLES

TABLE NO. 1: This table is for use with liquid asphaltic materials of gravity range (degrees A.P.I. at 60°F.) up to 14.9. The coefficient of expansion at 60°F. is approximately 0.00035. This table is for converting volumes of liquid asphaltic materials of all types as specified with the exception of such types as RC-1, MC-1, SC-1 and Gravel Dust Layer (D.H.O. Specifications).

Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor
60	1.0000	130	.9762	200	.9527	270	.9294	340	.9064
62	.9993	132	.9755	202	.9520	272	.9287	342	.9057
64	.9986	134	.9749	204	.9513	274	.9280	344	.9051
66	.9980	136	.9742	206	.9506	276	.9274	346	.9044
68	.9973	138	.9735	208	.9500	278	.9267	348	.9038
70	.9966	140	.9728	210	.9493	280	.9260	350	.9031
72	.9959	142	.9722	212	.9486	282	.9254	352	.9025
74	.9952	144	.9715	214	.9480	284	.9247	354	.9018
76	.9945	146	.9708	216	.9473	286	.9241	356	.9012
78	.9939	148	.9701	218	.9466	288	.9234	358	.9005
80	.9932	150	.9695	220	.9460	290	.9228	360	.8999
82	.9925	152	.9688	222	.9453	292	.9221	362	.8992
84	.9918	154	.9681	224	.9446	294	.9214	364	.8986
86	.9912	156	.9674	226	.9440	296	.9208	366	.8979
88	.9905	158	.9668	228	.9433	298	.9201	368	.8973
90	.9898	160	.9661	230	.9426	300	.9195	370	.8966
92	.9891	162	.9654	232	.9420	302	.9188	372	.8960
94	.9884	164	.9647	234	.9413	304	.9181	374	.8953
96	.9878	166	.9641	236	.9406	306	.9175	376	.8947
98	.9871	168	.9634	238	.9400	308	.9168	378	.8940
100	.9864	170	.9627	240	.9393	310	.9162	380	.8934
102	.9857	172	.9621	242	.9386	312	.9155	382	.8927
104	.9850	174	.9614	244	.9380	314	.9149	384	.8921
106	.9844	176	.9607	246	.9373	316	.9142	386	.8914
108	.9837	178	.9600	248	.9367	318	.9135	388	.8908
110	.9830	180	.9594	250	.9360	320	.9129	390	.8901
112	.9823	182	.9587	252	.9353	322	.9122	392	.8895
114	.9816	184	.9580	254	.9347	324	.9116	394	.8888
116	.9810	186	.9573	256	.9340	326	.9109	396	.8882
118	.9803	188	.9567	258	.9333	328	.9103	398	.8876
120	.9796	190	.9560	260	.9327	330	.9096	400	.8869
122	.9789	192	.9553	262	.9320	332	.9090		
124	.9783	194	.9547	264	.9313	334	.9083		
126	.9776	196	.9540	266	.9307	336	.9077		
128	.9769	198	.9533	268	.9300	338	.9070		

CONVERSION TABLES

TABLE NO. 2: This table is for use with liquid asphaltic materials of gravity range (degrees A.P.I. at 60°F.) of from 15.0 to 34.9. The coefficient of expansion at 60°F. is approximately 0.00040. This table is for converting volumes of liquid asphaltic materials of such types as RC-1, MC-1, SC-1 and Gravel Dust Layer (D.H.O. Specifications).

Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor	Temp. °F.	Conversion Factor
60	1.0000	98	.9849	136	.9701	174	.9555	212	.9412
61	.9996	99	.9845	137	.9697	175	.9551	213	.9408
62	.9992	100	.9841	138	.9694	176	.9547	214	.9405
63	.9988	101	.9837	139	.9690	177	.9543	215	.9401
64	.9984	102	.9833	140	.9686	178	.9540	216	.9397
65	.9980	103	.9830	141	.9682	179	.9536	217	.9393
66	.9976	104	.9826	142	.9678	180	.9532	218	.9390
67	.9972	105	.9822	143	.9675	181	.9528	219	.9386
68	.9968	106	.9818	144	.9671	182	.9524	220	.9382
69	.9964	107	.9814	145	.9667	183	.9521	221	.9378
70	.9960	108	.9811	146	.9663	184	.9517	222	.9374
71	.9956	109	.9807	147	.9659	185	.9513	223	.9371
72	.9952	110	.9803	148	.9655	186	.9509	224	.9367
73	.9948	111	.9799	149	.9651	187	.9505	225	.9363
74	.9944	112	.9795	150	.9647	188	.9502	226	.9359
75	.9940	113	.9791	151	.9643	189	.9498	227	.9356
76	.9936	114	.9787	152	.9639	190	.9494	228	.9352
77	.9932	115	.9783	153	.9636	191	.9490	229	.9349
78	.9929	116	.9778	154	.9632	192	.9487	230	.9345
79	.9925	117	.9775	155	.9628	193	.9483	231	.9341
80	.9921	118	.9771	156	.9624	194	.9480	232	.9337
81	.9917	119	.9767	157	.9620	195	.9476	233	.9334
82	.9913	120	.9763	158	.9616	196	.9472	234	.9330
83	.9909	121	.9759	159	.9612	197	.9468	235	.9326
84	.9905	122	.9755	160	.9608	198	.9465	236	.9322
85	.9904	123	.9752	161	.9604	199	.9461	237	.9318
86	.9901	124	.9748	162	.9601	200	.9457	238	.9315
87	.9897	125	.9744	163	.9597	201	.9453	239	.9311
88	.9893	126	.9740	164	.9594	202	.9449	240	.9307
89	.9889	127	.9736	165	.9590	203	.9446	241	.9303
90	.9885	128	.9732	166	.9586	204	.9442	242	.9300
91	.9881	129	.9728	167	.9582	205	.9438	243	.9296
92	.9877	130	.9724	168	.9578	206	.9434	244	.9293
93	.9869	131	.9720	169	.9574	207	.9430	245	.9289
94	.9865	132	.9716	170	.9570	208	.9427	246	.9285
95	.9861	133	.9713	171	.9566	209	.9423	247	.9281
96	.9857	134	.9709	172	.9562	210	.9419	248	.9278
97	.9853	135	.9705	173	.9559	211	.9415	249	.9274

(g) GRAVITY CONVERSION EQUATIONS

SPECIFIC GRAVITY TO DEGREES A.P.I. GRAVITY: Crude petroleum and liquid petroleum products are generally reported in terms of A.P.I Gravity (A.S.T.M. D-287-28T) which may be obtained from Specific Gravity as follows:

$$°\text{A.P.I.} = \frac{141.5}{\text{Specific Gravity } 60°/60°\text{F.}} - 131.5$$

SPECIFIC GRAVITY TO DEGREES BAUMÉ AND VICE VERSA:

FOR LIQUIDS LIGHTER THAN WATER:

$$°\text{Baumé} = \frac{140}{\text{Specific Gravity } 60°/60°\text{ F.}} - 130$$

$$\text{Specific Gravity} = \frac{140}{130 + °\text{Baumé}}$$

FOR LIQUIDS HEAVIER THAN WATER:

$$°\text{Baumé} = 145 - \frac{145}{\text{Specific Gravity } 60°/60°\text{F.}}$$

$$\text{Specific Gravity } 60°/60°\text{F.} = \frac{145}{145 - °\text{Baumé}}$$

CHAPTER IV

MINERALS and MINERAL AGGREGATE

(a) GLOSSARY OF TERMS RELATING TO MINERALS AND MINERAL AGGREGATE

AGGREGATE: The inert material such as sand, gravel, shell, slag, or broken stone or combination thereof with which the cementing material is mixed to form a mortar or concrete.

ALLUVIUM: Deposits of mud and silt commonly found on the flat lands along the lower courses of streams.

BANK GRAVEL: Gravel found in natural deposits, usually more or less mixed with fine material, such as sand or clay or combinations thereof; gravelly clay, gravelly sand, clayey gravel, and sandy gravel indicating varying proportions of the materials in the mixture.

BENTONITE: The plastic residue from the weathering of volcanic ash; it swells enormously in water and forms a milky suspension.

BOULDERS: Detrital material greater than 200 mm., or about 8 in., in diameter.

CLAY: A fine, argillaceous material which is more or less plastic when wet. The most important constituent of clay is hydrous aluminum silicate gel, a colloidal material, which remains suspended indefinitely in water but may be thrown down as coagulated material by salt solutions. When dry, clay is a fine earthy material. When pure it is white, but it is commonly colored yellow, brown or red by iron oxides or grey, blue or black by organic substances. The grain size of clay is commonly considered as minus 0.005 mm.

CRUSHER RUN: Refers to the product of the crushing plant without being rescreened or separated into various sizes.

DENSITY: is the weight per unit volume of a substance. In the centimeter-gram-second system, density is expressed in grams per cubic centimeter. In the foot-pound-second system, density is expressed in pounds per cubic foot.

There are two densities in reference to materials made up of solids and voids. "Absolute Density" is the density of the solids. "Bulk Density" is the density of the mass. The general term "density" refers to "Bulk Density".

DIATOMACEOUS ROCK: Essentially composed of siliceous skeletons of diatoms, extremely minute unicelled organisms. It is composed mainly of silica, white or grey in color, and is extremely porous.

DOLOMITE: A magnesium limestone, composed essentially of the mineral dolomite—a double carbonate of calcium and magnesium. It is theoretically composed of 54 percent of calcium carbonate and 46 percent of magnesium carbonate.

FAULTS: May be considered as an abrupt break in the continuity of the beds or strata with the elevation or depression of beds on one side of the plane of the fault.

FIELD STONE: Loose rock commonly of assorted sizes and character found upon the surface of the ground. Such material is usually associated with nearby outcrops of rock.

GNEISS: A medium—or coarse-grained crystalline rock possessing some form of parallel structure due either to the uniform orientation of certain tabular or prismatic minerals or to the presence of wavy, discontinuous surfaces indicating a lenticular structure or of bands of varying mineralogical composition which retain their continuity and parallelism throughout a considerable mass of rock. Examples are banded gneiss, granite gneiss, etc.

GRANITES: Are crystalline, even-grained rocks consisting essentially of feldspar and quartz with smaller amounts of mica and other ferromagnesian minerals.

GRAVEL: The granular, pebbly material (usually coarser than ¼″ in diameter) resulting from the natural disintegration of rock. The rounded character of some gravel particles has been imparted by stream action.

GUMBO: The natural soil found in certain parts of the Middle West, which consists of finely divided clays of varying capillarity.

HYDROPHILIC AGGREGATE is one in which the affinity of the aggregate for water is greater than the affiinity of the aggregate for bituminous material.

HYDROPHOBIC AGGREGATE is one in which the affinity of the aggregate for bituminous material is greater than the affinity of the aggregate for water.

IGNEOUS ROCK: Are those which have been formed or crystallized from molten magmas, the source of which has been the earth's interior.

LOESS: Is wind-blown silt or silty clay having little or no stratification. Some of its peculiarities are the light color, fine state of subdivision, the sharpness and angularity of its particles, its porosity and coherence.

METAMORPHIC ROCKS: These rocks have been changed by temperature, pressure, and chemical fluids into new forms, being more stable under the new conditions. Examples are gneisses, schists, marbles, etc.

OVERBURDEN: Refers to the soil mantle, waste material, or other similar matter found directly above the deposit of rock or sand gravel. The amount of this overburden has a direct economic effect on the amount of material capable of being produced.

PEBBLES: Rock fragments of small or moderate size which have been more or less rounded by erosional processes.

QUARTZITE: A dense sandstone rock which has been thoroughly cemented by silica or which has been indurated or hardened by a recrystallization process.

QUARTZ: Is composed entirely of silica; is colorless when pure, but often tinted yellow, red, blue, voilet. It has a specific gravity of 2.65 and is the most common mineral in sand.

RIFT (OF ROCK): The direction of easiest splitting as referred to by quarrymen.

ROCK ASPHALT: A porous rock which has become naturally more or less impregnated with asphalt or malta.

SAND: The fine, granular material, usually less than ¼″ in diameter, resulting from the natural disintegration of rock or from the crushing of friable sandstone rocks.

SANDSTONE: A typical sandstone is composed essentially of rounded grains of quartz, with or without interstitial cementing material, with the larger grains tending to be more perfectly rounded than the smaller ones. The fracture in sandstone takes place usually in the cement, leaving the grains outstanding, thus giving the rock the appearance and feeling of loaf sugar.

SCHISTS: Differ from gneiss in being of finer grain and in possessing a well-marked tendency to split into thin layers, except when puckered or folded by movement subsequent to the development of schistosity. Examples are mica schist, sericite schist, etc.

SCREENINGS: The broken rock, including the dust of a size that will pass through ½″ to ¾″ screen, depending upon the character of the stone.

SEDIMENTARY ROCKS: Are formed by the decay of existing strata with subsequent deposition of the solid matter that has been carried in suspension by agencies of transportation to some point where they have been redeposited.

SHALE: A material composed essentially of silica and alumina, which has, in addition, a more or less thinly laminated structure. This structure has been imparted by the natural stratification of extremely fine sediments together with more or less pressure.

SILT: Consists of the finer particles of rock substance and ranges in size from 0.05 to 0.005 mm.

SLATES: Are rocks, normally clayey in composition, in which pressure has produced a perfect cleavage, so that a block of slate can be readily split into thin, smooth, tough plates.

SOIL: A mixture of fine, earthy material with more or less organic matter resulting from the growth and decomposition or vegetable or animal matter.

SPALL: A small piece or fragment broken from a larger piece of rock.

SPECIFIC GRAVITY is the ratio of the density of a substance to the density of water, at the same temperature.

There are two specific gravities in reference to materials made up of solids and voids (i.e. gravels, soils, paving mixtures, etc.). "Absolute Specific Gravity" is the specific gravity of the solids. "Bulk or Apparent Specific Gravity" is the specific gravity of the mass. The general term "Specific Gravity" refers to "Absolute Specific Gravity".

STABILITY in a road material is its ability to resist motion and this resistance is supplied primarily by the grading of the aggregate.

STONE: Any natural deposit or formation of igneous, sedimentary, and/or metamorphic origin, either in its original or altered form.

SUBGRADE: The upper surface of the native foundaton on which is placed the road metal or artificial foundation, in case the latter is provided.

SUBSOIL: The bed of earth immediately beneath the surface soil.

TAILINGS: Stones which after going through the crusher do not pass through the largest openings of the screen.

TOPSOIL (ROAD SURFACE): A variety of surfacing being the stripping of certain topsoils which contain a natural sand-clay mixture. When placed on a road surface, wetted and puddled under traffic it develops considerable stability.

TRAP: Includes the dark-colored, fine-grained and dense igneous rocks composed essentially of the ferromagnesian minerals, basic feldspars, and little or no quartz. The ordinary commercial variety of trap is basalt, diabase or gabbro.

(b) APPOXIMATE WEIGHTS OF SOME MINERAL MATERIALS

Material	Specific Gravity	Pounds cu. ft.	Pounds cu. yd.
SAND AND GRAVEL			
(50% voids)	2.65	83	2240
(45% voids)	2.65	91	2460
(40% voids)	2.65	99	2680
(35% voids)	2.65	108	2910
(30% voids)	2.65	116	3130
(25% voids)	2.65	124	3350
(20% voids)	2.65	132	3565
(15% voids)	2.65	140	3780
CRUSHED GRANITE AND TRAP ROCK			
loose spread...(45% voids)	2.8	96	2590
compacted....(30% voids)	2.8	122	3300
loose spread...(45% voids)	2.9	99	2680
compacted....(30% voids)	2.9	127	3420
loose spread...(45% voids)	3.0	103	2770
compacted....(30% voids)	3.0	131	3540
loose spread...(45% voids)	3.1	106	2870
compacted....(30% voids)	3.1	135	3650
CRUSHED LIMESTONE			
loose spread...(45% voids)	2.6	89	2400
compacted....(30% voids)	2.6	113	3060
loose spread...(45% voids)	2.7	93	2500
compacted....(30% voids)	2.7	118	3180
loose spread...(45% voids)	2.8	96	2590
compacted....(30% voids)	2.8	122	3300
SANDSTONE			
loose spread...(45% voids)	2.4	82	2220
compacted....(30% voids)	2.4	105	2830
loose spread...(45% voids)	2.5	86	2310
compacted....(30% voids)	2.5	109	2940
loose spread...(45% voids)	2.6	89	2400
compacted....(30% voids)	2.6	113	3060
loose spread...(45% voids)	2.7	93	2500
compacted....(30% voids)	2.7	118	3180
CRUSHED SLAG		74	2000
CLAY-BEARING SOIL			
dry loose		80	2160
dry compacted		133	3600

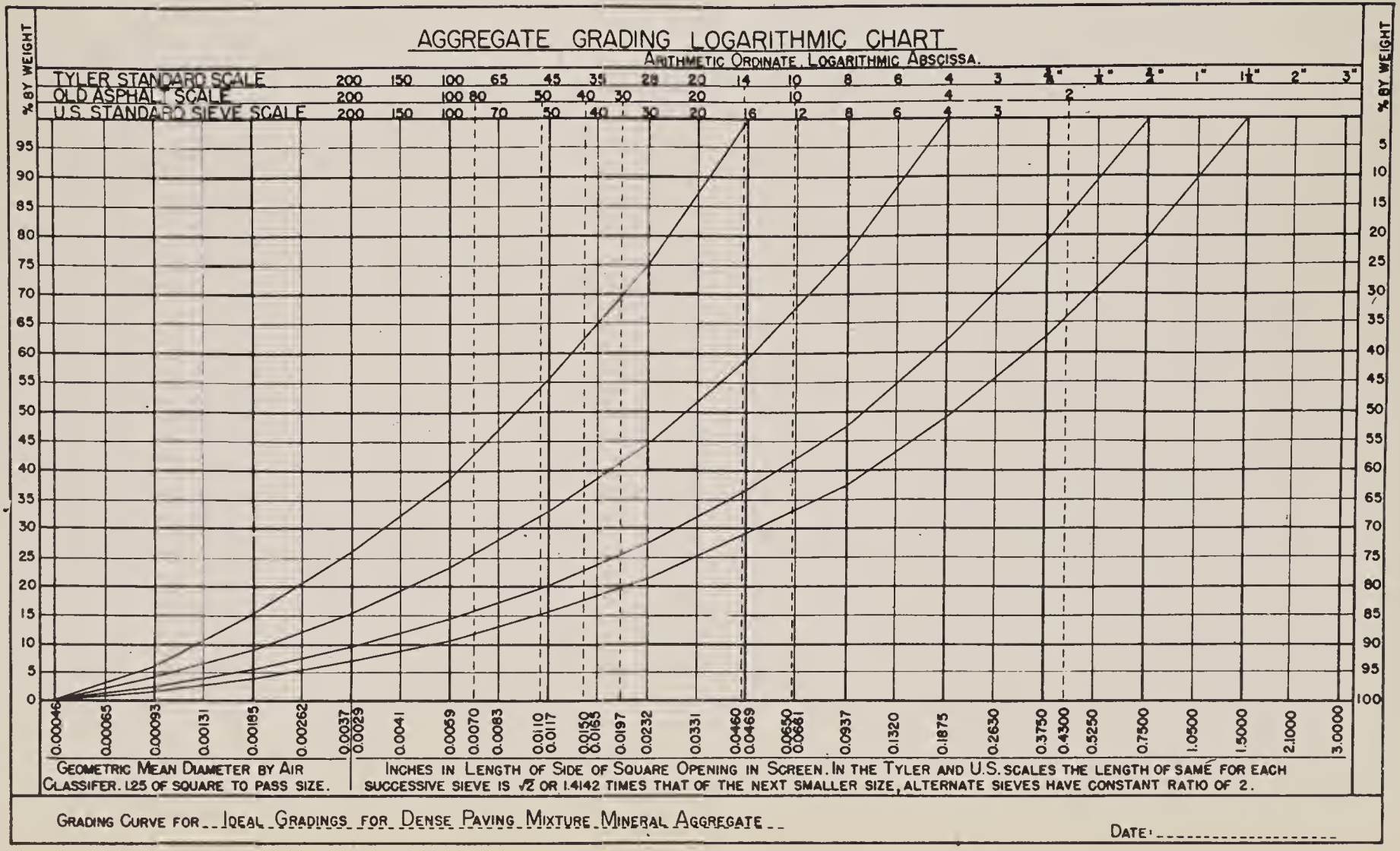
(c) IDEAL MINERAL AGGREGATE GRADING FOR DENSE PAVING MIXTURES

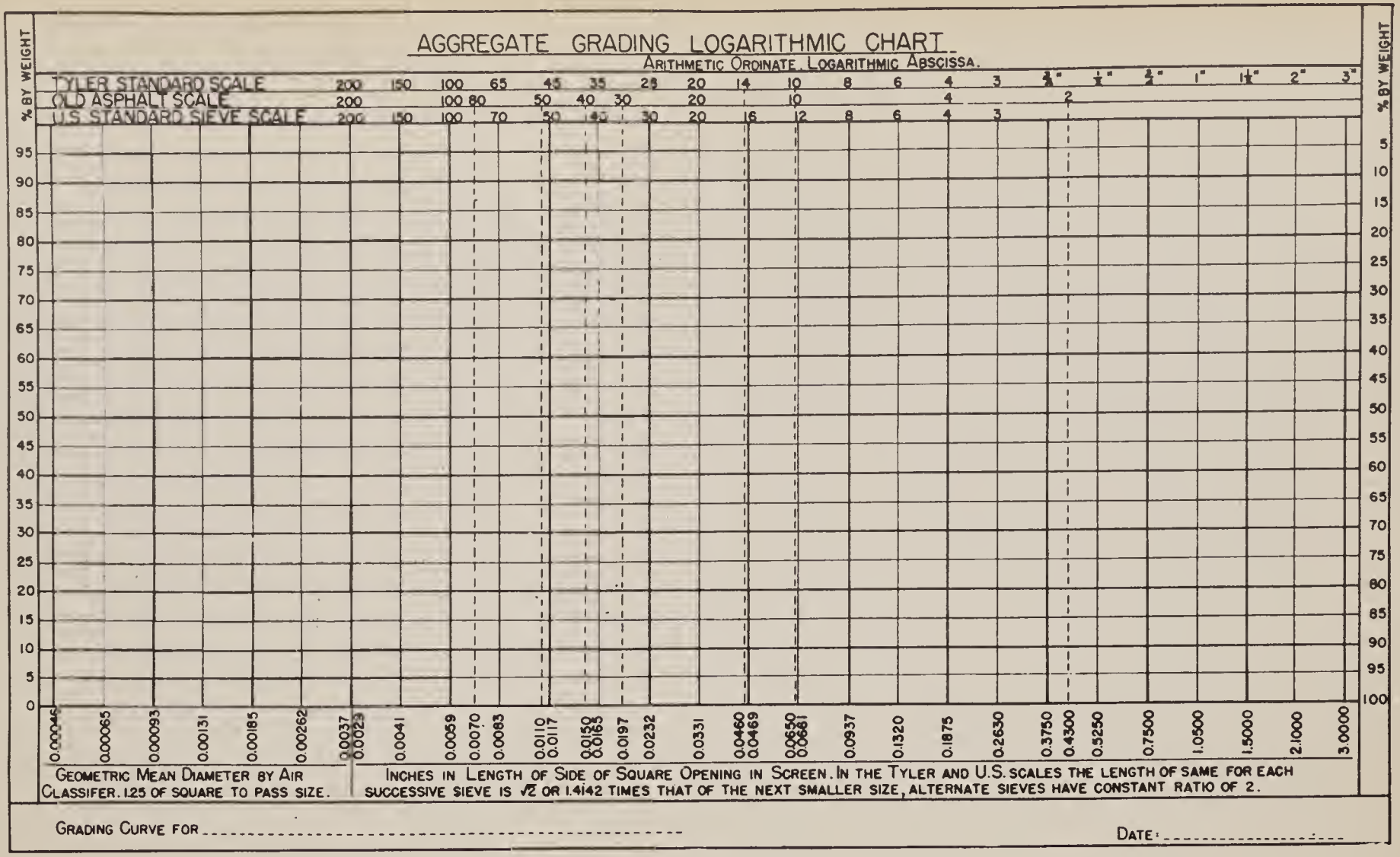
The curves on the following logarithmic chart show the gradings of mixtures of varying maximum size groups based on 100% mineral aggregate. For these calculations a specific gravity of 2.70 has been assumed for the mineral aggregate. Curves for mixtures of other than the shown maximum sizes would fall in a relative position on the chart.

Assuming a specific gravity of 1.00 for asphalt, the ideally graded aggregates would theoretically require amounts of asphalt as follows:

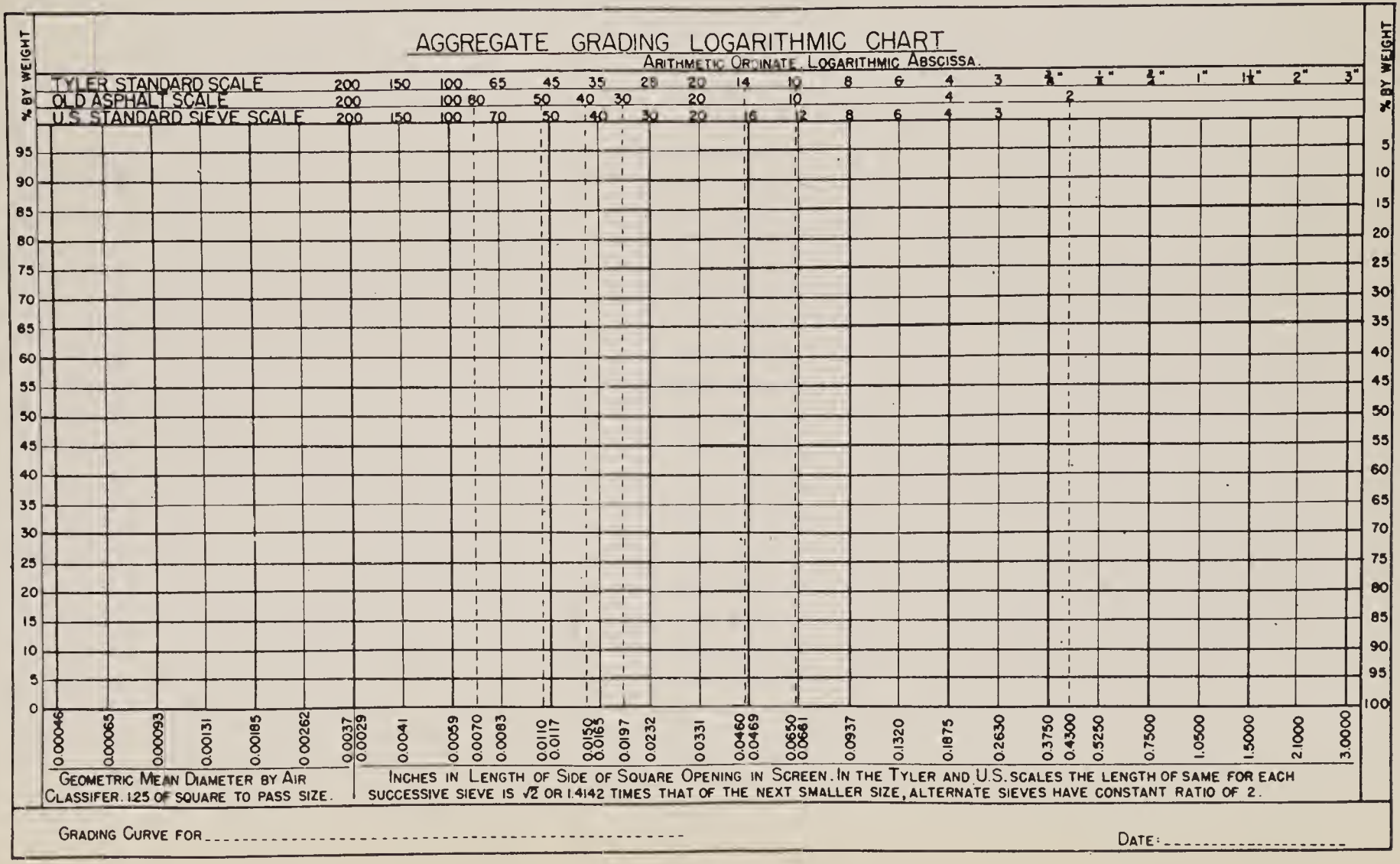
Maximum Size of Grading	Theoretical % Asphalt
1½″ square	3.05
¾″ square	3.72
4 mesh	5.70
16 mesh	9.50

If a mixture is not ideally graded, the asphalt requirements change considerably and must be adapted in accordance with the change in the grading of the mixture. It is almost impossible in practice to produce ideally graded mixtures, particularly due to the lack of control of the material passing the 200 mesh sieve. However, grading curves approaching those shown can and should be obtained if the production of dense mixtures is required.


AGGREGATE GRADING LOGARITHMIC CHART
Arithmetic Ordinate, Logarithmic Abscissa.
% BY WEIGHT
TYLER STANDARD SCALE
OLD ASPHALT SCALE
U.S. STANDARD SIEVE SCALE
200 150 100 65 45 35 28 20 14 10 8 6 4 3 ½" ¾" 1" 1½" 2" 3"
200 100 80 50 40 30 20 10 4 2
200 150 100 70 50 40 30 20 16 12 8 6 4 3
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0.00046 0.00065 0.00093 0.00131 0.00185 0.00262 0.0037 0.0029 0.0041 0.0059 0.0070 0.0083 0.0110 0.0117 0.0150 0.0165 0.0197 0.0232 0.0331 0.0460 0.0469 0.0650 0.0661 0.0937 0.1320 0.1875 0.2630 0.3750 0.4300 0.5250 0.7500 1.0500 1.5000 2.1000 3.0000
Geometric Mean Diameter by Air Classifer. 1.25 of square to pass size.
Inches in Length of Side of Square Opening in Screen. In the Tyler and U.S. scales the length of same for each successive sieve is √2 or 1.4142 times that of the next smaller size, alternate sieves have constant ratio of 2.
Grading Curve for -- Ideal Gradings for Dense Paving Mixture Mineral Aggregate --
Date: ----------


AGGREGATE GRADING LOGARITHMIC CHART.
Arithmetic Ordinate. Logarithmic Abscissa.
% BY WEIGHT
TYLER STANDARD SCALE
OLD ASPHALT SCALE
U.S. STANDARD SIEVE SCALE
200 150 100 65 45 35 28 20 14 10 8 6 4 3 ¾" ½" ¼" 1" 1½" 2" 3"
200 100 80 50 40 30 20 10 4 2
200 150 100 70 50 40 30 20 16 12 8 6 4 3
95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0.0046 0.00065 0.00093 0.00131 0.00185 0.00262 0.0037 0.0023 0.0041 0.0059 0.0070 0.0083 0.0110 0.0117 0.0150 0.0165 0.0197 0.0232 0.0331 0.0460 0.0469 0.0650 0.0681 0.0937 0.1320 0.1875 0.2630 0.3750 0.4300 0.5250 0.7500 1.0500 1.5000 2.1000 3.0000
GEOMETRIC MEAN DIAMETER BY AIR CLASSIFER. 1.25 OF SQUARE TO PASS SIZE.
INCHES IN LENGTH OF SIDE OF SQUARE OPENING IN SCREEN. IN THE TYLER AND U.S. SCALES THE LENGTH OF SAME FOR EACH SUCCESSIVE SIEVE IS √2 OR 1.4142 TIMES THAT OF THE NEXT SMALLER SIZE, ALTERNATE SIEVES HAVE CONSTANT RATIO OF 2.
GRADING CURVE FOR
DATE:

Blank charts are available on request.


AGGREGATE GRADING LOGARITHMIC CHART
ARITHMETIC ORDINATE. LOGARITHMIC ABSCISSA.
% BY WEIGHT
TYLER STANDARD SCALE 200 150 100 65 45 35 28 20 14 10 8 6 4 3 3/8" 1/2" 3/4" 1" 1 1/2" 2" 3"
OLD ASPHALT SCALE 200 100 80 50 40 30 20 10 4 2
U.S. STANDARD SIEVE SCALE 200 150 100 70 50 40 30 20 16 12 8 6 4 3
95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0.00046 0.00065 0.00093 0.00131 0.00185 0.00262 0.0037 0.0029 0.0041 0.0059 0.0070 0.0083 0.0110 0.0117 0.0150 0.0165 0.0197 0.0232 0.0331 0.0460 0.0469 0.0650 0.0661 0.0937 0.1320 0.1875 0.2630 0.3750 0.4300 0.5250 0.7500 1.0500 1.5000 2.1000 3.0000
GEOMETRIC MEAN DIAMETER BY AIR CLASSIFER. 1.25 OF SQUARE TO PASS SIZE.
INCHES IN LENGTH OF SIDE OF SQUARE OPENING IN SCREEN. IN THE TYLER AND U.S. SCALES THE LENGTH OF SAME FOR EACH SUCCESSIVE SIEVE IS √2 OR 1.4142 TIMES THAT OF THE NEXT SMALLER SIZE, ALTERNATE SIEVES HAVE CONSTANT RATIO OF 2.
GRADING CURVE FOR
DATE:

Blank charts are available on request.

(d) THICKNESS OF COURSE AND AMOUNT OF MATERIAL SPREAD

The following equations (I) and (II) or the chart may be used when paving mixtures, stabilized mixtures or mineral aggregate courses are laid to determine any of the following:

(a) THICKNESS OF A COMPACTED COURSE from a specified weight per square yard to be spread.

(b) WEIGHT PER SQUARE YARD to be spread working to a specified thickness.

(c) THICKNESS OF AN UNCOMPACTED COURSE working to a specified weight per square yard to be spread.

The compacted or loose weight of the material, depending on the formula to be used must first be determined. This may be readily done in the field by the following methods.

With paving mixtures take a conveniently sized compacted sample, weigh it in air and in water and obtain a value for the compacted weight per cubic foot from:

$$\frac{\text{(WEIGHT IN AIR)}}{\text{(WEIGHT IN AIR)—(WEIGHT IN WATER)}} = \text{DENSITY}$$

DENSITY x 62.4 = POUNDS PER CUBIC FOOT

With stabilized mixtures and aggregates, compact, measure the volume and weigh a convenient amount of the mixture or material. A cubic foot measure may be used and a value directly determined for density expressed in pounds per cubic foot compacted weight.

For determination of (c) it is necessary to weigh a measured volume of the material in an uncompacted state and determine a value for pounds per cubic foot uncompacted weight.

EQUATION I: Used for determining (a) and (b).

INCHES OF COMPACTED COURSE

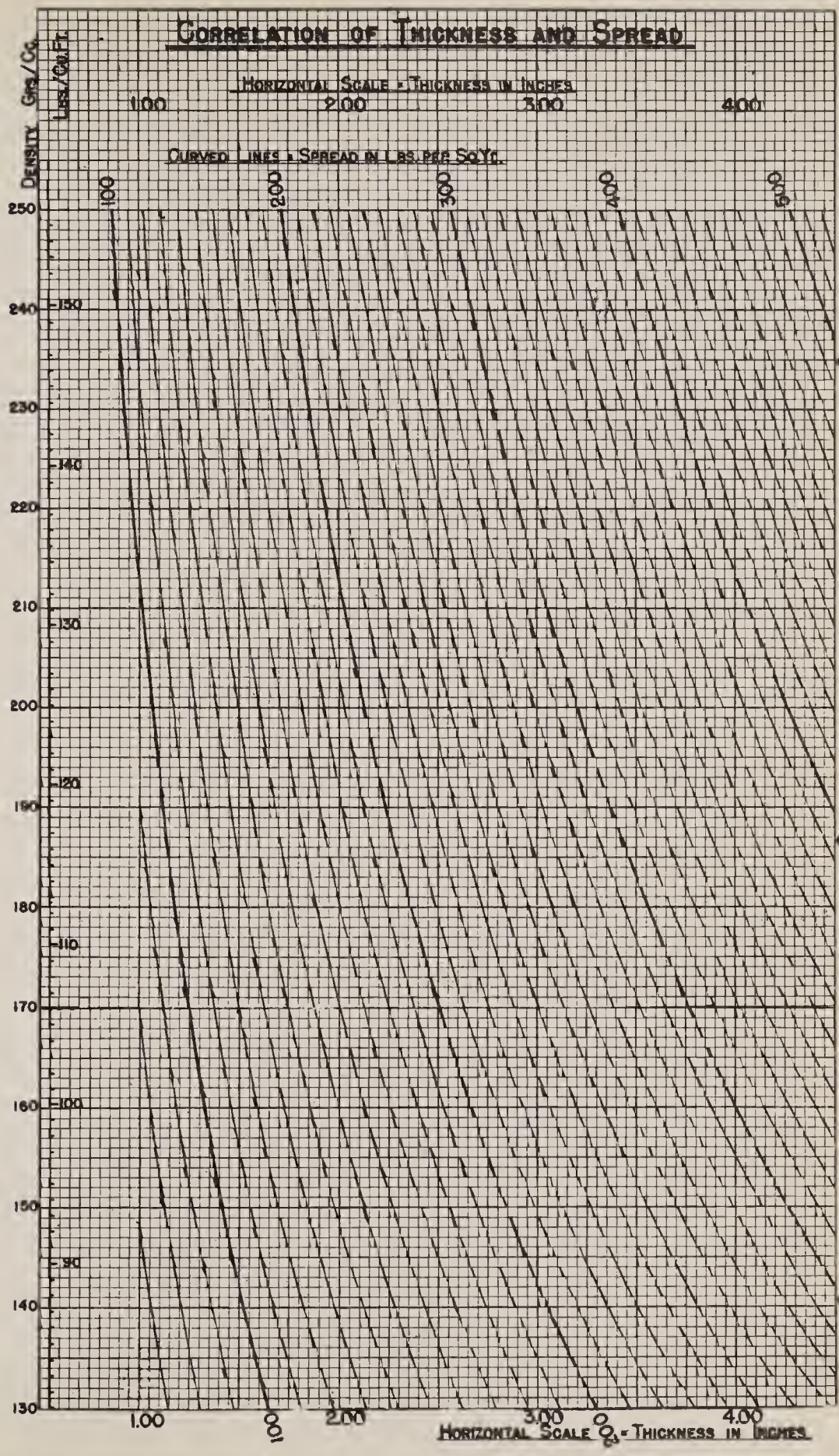
$$= \frac{\text{Lbs. per sq. yd. spread}}{\text{Lbs. per cu. ft. Compacted Weight x .75}}$$

EQUATION II: Used for determining (c).

INCHES OF UNCOMPACTED COURSE

$$= \frac{\text{Lbs. per sq. yd. spread}}{\text{Lbs. per cu. ft. Loose Weight x .75}}$$

The chart on the following page may be used to quickly obtain any of the above values. For example, that point where the horizontal line representing the experimentally obtained value for density, intersects the curve which represents the rate in pounds per square yard at which the material has been spread, will fall vertically on the horizontal scale to a reading which is the thickness in inches of compacted course. Inversely, one may ascertain the amount of spread in pounds per square yard necessary to give a required thickness.


CORRELATION OF THICKNESS AND SPREAD
HORIZONTAL SCALE = THICKNESS IN INCHES
1.00
2.00
3.00
4.00
CURVED LINES = SPREAD IN LBS. PER SQ.YD.
100
200
300
400
600
DENSITY Grs./Cc.
Lbs./Cu.Ft.
250
240
150
230
140
220
210
130
200
120
190
180
110
170
160
100
150
90
140
130
500
400
300
1.00
2.00
3.00
4.00
HORIZONTAL SCALE = THICKNESS IN INCHES

(e) TONS OF AGGREGATE REQUIRED PER MILE

Pounds per Sq.Yd.	WIDTH OF ROADWAY					Pounds per Sq.Yd.	WIDTH OF ROADWAY				
	16′	18′	20′	22′	24′		16′	18′	20′	22′	24′
10	47	53	59	65	70	230	1080	1214	1349	1484	1619
15	70	79	88	97	106	240	1127	1267	1408	1549	1690
20	94	106	117	129	141	250	1173	1320	1467	1613	1760
25	117	132	147	161	176	260	1220	1373	1525	1678	1830
30	141	158	176	194	211	270	1267	1426	1584	1742	1901
35	164	185	205	226	246	280	1314	1478	1643	1807	1971
40	188	211	235	258	282	290	1361	1531	1701	1872	2042
45	211	238	264	290	317	300	1408	1584	1760	1936	2112
50	235	264	293	323	352	310	1455	1637	1819	2000	2182
60	281	317	352	387	422	320	1502	1690	1877	2065	2253
70	329	370	411	452	493	330	1549	1742	1936	2129	2323
80	375	422	469	516	563	340	1596	1795	1995	2194	2394
90	422	475	528	581	634	350	1643	1848	2053	2258	2464
100	469	528	587	645	704	360	1689	1901	2112	2323	2534
110	516	581	645	710	774	370	1736	1954	2171	2387	2605
120	563	634	704	774	845	380	1783	2006	2229	2452	2675
130	610	686	763	839	915	390	1830	2059	2288	2517	2746
140	657	739	821	904	986	400	1877	2112	2347	2581	2816
150	704	792	880	968	1056	410	1924	2165	2405	2646	2886
160	751	845	939	1033	1126	420	1971	2218	2464	2710	2957
170	798	898	997	1097	1197	430	2018	2270	2523	2775	3027
180	845	950	1056	1162	1267	440	2065	2323	2581	2839	3098
190	892	1003	1147	1226	1338	450	2112	2376	2640	2904	3168
200	939	1056	1173	1291	1408	460	2159	2429	2699	2968	3238
210	986	1109	1232	1355	1478	470	2206	2482	2757	3033	3309
220	1033	1162	1291	1420	1549	480	2253	2534	2816	3097	3379

* By subsequent reference to this table "Tons of Aggregate Required Per Mile" the quantities per mile required for jobs of various width may be quickly ascertained.

(f) U.S. Bureau Standards Sieve Series and Equivalents

U.S.B.S. Sieve No.	No. Openings per lineal inch	SIEVE OPENING	
		Inches	Millimeters
4	4.22	0.187	4.76
8	7.89	0.0937	2.38
10	9.21	0.0787	2.00
12	10.72	0.0661	1.68
14	12.58	0.0555	1.41
16	14.66	0.0469	1.19
20	20.16	0.0331	0.89
30	27.62	0.0232	0.59
40	38.02	0.0165	0.42
50	52.36	0.0117	0.297
100	101.01	0.0059	0.149
200	200.00	0.0029	0.074
270	270.26	0.0021	0.053
325	323.00	0.0017	0.044

CHAPTER V

SOILS

The following data on soils is, in the main part, based on work done and literature published by the United States Bureau of Roads, C. A. Hogentogler, C.E., Senior Highway Engineer. This source of reference is generally accepted as the standard in this country.

(a) GLOSSARY OF TERMS APPLYING TO SOILS:

CAPILLARITY: Capillary moisture is the free or pore moisture which adhesive films lift above the water table and which is held by its surface tension of free water at a distance termed the "capillary rise" above the water table.

CAPILLARY FRINGE: The layer of soil moistened by capillary moisture in the zone of aeration above the water table.

CLAY: Fine argillaceous material which is more or less plastic when wet. The most important constituent of clay is hydrous aluminum silicate gel, a colloidal material which remains suspended indefinitely in water but may be thrown down as coagulated material by salt solutions. When dry, clay is a fine earthy material. When pure, it is white but it is commonly coloured yellow, brown or red by iron oxides or grey, blue or black by organic substances. The grain size of clay is generally considered to be less than 0.005 mm. Clay gives properties of cohesion to a soil mixture and clay is indicative of compressibility.

COLLOIDS: Those particles finer than 0.001 mm. in size. In a limited sense, those finer clay particles which show pronounced Brownian movement when suspended in water. Colloids give properties of cohesion to a soil mixture. When not flocculated they are indicative of compressibility.

COMPRESSIBILITY: Compressibility is the property of compressing vertically under a load without lateral movement and with a proportional decrease in air or moisture content.

DIATOMS: OR DIATOMACEOUS EARTH: Essentially composed of siliceous skeletons of dead marine and fresh-water plants and microscopic particles. It is composed mainly of silica, white or grey in colour, and extremely porous. Diatoms give properties of detrimental capillarity to a soil mixture.

EFFECTIVE SIZE: The grain diameter of which 10% of the soil mixture is finer. The maximum size of the smallest 10 percent, by weight, of the soil particles.

ELASTICITY: The property of deforming under load and rebounding, upon removal of load, without change of moisture content.

GRAVEL: The granular pebbly material resulting from the natural disintegration of rock. Limited to that size fraction which is held on a 10 mesh sieve (2 mm.). Gravel gives properties indicative of high internal friction to a soil mixture.

MICA FLAKES: A type of refractory material which occurs in the form of perfect crystals. Mica flakes give properties of elasticity to a soil mixture.

PEAT SOIL: Is composed predominantly of highly fibrous organic material with easily recognized plant remains. Peat gives properties of detrimental capillarity and elasticity to soil mixtures.

SAND: The fine granular material resulting from the natural disintegration of rock or the crushing of friable sandstone rocks. Sand gives properties of high internal friction to a soil mixture.

COARSE SAND: Is that fraction passing the 10 mesh sieve (2 mm.) and held on a 40 mesh sieve (.042 mm.).

FINE SAND: Is that fraction passing the 40 mesh sieve (0.42 mm.) and held on the 270 mesh sieve (0.05 mm).

SILT: The finer particles of rock substances, similar to fine sand in all respects other than particle size, which range in size from 0.05 mm. to 0.005 mm. in diameter. Silt gives properties of detrimental capillarity to a soil mixture.

SOIL FINES: That fraction of a soil mixture which passes the 10 mesh sieve.

STABILITY: The property of resisting lateral flow.

UNIFORMITY COEFFICIENT: The grain diameter for which 60% was finer, divided by the grain diameter for which 10% was finer.

(b) TERMS RELATIVE TO TESTS ON SOILS:

CENTRIFUGE MOISTURE EQUIVALENT: (C.M.E.): The centrifuge moisture equivalent of a soil is the amount of moisture, expressed as a percentage of the weight of the oven-dried soil, retained by the soil which has been first saturated with water and then subjected to a force equal to 1,000 times the force of gravity for one hour (A.S.T.M. D 425-39). Detrimental frost heave is unlikely to occur in soils having a C.M.E. of less than 12.

FIELD MOISTURE EQUIVALENT (F.M.E.): The field moisture equivalent of a soil is defined as the minimum moisture content, expressed as a percentage of the weight of the oven-dried soil, at which a drop of water placed on the smoothed surface of the soil will not immediately be absorbed but will spread out over the surface and give it a shiny appearance (A.S.T.M. D 426-39).

LINEAL SHRINKAGE (L.S.): The lineal shrinkage of a soil for a given moisture content is the decrease in one dimension, expressed as a percentage of the original dimension, of the soil mass when the moisture content is reduced from an amount equal to the field moisture equivalent to the shrinkage limit (A.S.T.M. D 427-39).

LIQUID LIMIT (L.L.): The liquid limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil will just begin to flow when jarred ten times (A.S.T.M. D 423-39).

OPTIMUM MOISTURE CONTENT: Is the percentage of moisture required in a soil mixture which will enable that mixture to be compacted to the maximum stability. This will vary with different varieties of the same material, depending upon variables such as percentage of voids; and the size, shape and surface texture of the particles which make up the material.

PLASTIC LIMIT (P.L.): The plastic limit of a soil is the lowest moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil can be rolled into threads $\frac{1}{8}$" in diameter without the thread breaking into pieces (A.S.T.M. D 424-39).

PLASTICITY INDEX (P.I.): The plasticity index of a soil is the difference between its liquid limit and its plastic limit.

SHRINKAGE LIMIT: The shrinkage limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which a reduction in moisture content will not cause a decrease in the volume of the soil mass, but at which an increase in the moisture content will cause an increase in the volume of the soil mass. (A.S.T.M. D 427-39).

SHRINKAGE RATIO: The shrinkage ratio of a soil is the ratio between a given volume change, expressed as a percentage of the dry volume, and the corresponding change in the moisture content above the shrinkage limit, expressed as a percentage of the weight of the oven-dried soil. It equals the apparent specific gravity of the dried soil pat (A.S.T.M. D 427-39).

SPECIFIC GRAVITY: The specific gravity of a soil is the weight of the oven-dried soil divided by the true volume of the soil particles (A.S.T.M. D 427-39).

NOTE: See Density and Specific Gravity under "Glossary of Terms Relative to Mineral Aggregate".

VOLUMETRIC CHANGE: The volumetric change of a soil for a given moisture content is the volume change, expressed as a percentage of the dry volume, of the soil mass when the moisture content is reduced from the stipulated percentage to the shrinkage limit. This stipulated moisture content is usually taken as the field moisture equivalent (A.S.T.M. D 427-39).

(c) CLASSIFICATION OF SOIL GROUPS

Work done by the United States Bureau of Roads (C. A. Hogentogler, C.E., Senior Highway Engineer) has established the generally accepted classification of eight soil groups as shown on the following pages:

Soil Classification According to U.S.

Type	Grading	Tests on 40M. Fraction				
		L.L.*	P.I.*	S.L.*	F.M.E.	C.M.E.
A-1	Held on 10M—Less than 50%. Soil Mortar(pass.10mm) Total Sand...70-85% Coarse Sand..35-50% Silt.....10-20% Clay..... 5-10%	14-25	<8 Curve 2	14-20	—	<15
A-2	Not less than 55% of sand in the Soil Mortar.....	<35	0	—	—	<25
A-3	Effective Size greater than 0.10mm.....	<35	0	—	—	<12
A-4	Less than 55% sand...	20-40	<Curve 3	<25	>Curve 11 <30	12-50

Bureau of Public Roads System

General Remarks	Structural Properties	Suggested Treatment for Stabilization
Average Effective Size—.01mm. Uniformity Coefficient is greater than 15.	Well-graded coarse to fine aggregate. Excellent binder. High stability under wheel loads under all moisture conditions.	Provide drainage to maintain ground water below level of frost penetration. Puddle and compact with sheepsfoot roller.
There may be a 0 P.I. with a significant S.L., or a P.I. of, more than 0 and less than 15, with or without a significant S.L.	Improper grading or inferior binder. Soil may be friable in dry weather and fairly stable in wet weather; or stable dry and soft when wet.	Puddle and compact after intermixing the required quantities of gravel, crushed stone or sand if soil lacks coarse material. If cohesive material is lacking add clay or silt to give a P.I. of 3 to 5. If the soil mortar has high shrinkage properties treat with hydrated lime to increase porosity, then bituminous material to reduce capillary moisture.
Angular or round grained sands. L.L. of 10-14 indicate beach sand which flow easily. L.L. of 30-35 indicate rough angular sands.	Sand or coarse material with no binder. Good drainage properties and is not heaved with frost.	An admixture of binder soil or bituminous material is desirable. Puddle and compact.
Expansive properties are indicated with a S.L. exceeding 20, especially when the F.M.E. is greater than the C.M.E.	Mostly silts without coarse material and little clay content. Will absorb water readily with a rapid loss of stability. High capillarity and subject to excess frost heave when wet.	Provide drainage to intercept seepage. A beneficial treatment may be the admixture of suitable cohesive material into the subgrade. Sprinkle moderately and compact. Then stage construction, bituminous application and cushion courses under the pavement. In extreme cases, the natural soil should be replaced with non-heaving material to the lower limit of frost penetration. With high ground water elevation and impractical drainage, asphaltic pavement is not desirable and a thick, heavily reinforced concrete type is required.

Soil Classification According to U.S.

Type	Grading	Tests on 40M. Fraction				
		L.L.*	P.I.*	S.L.*	F.M.E.*	C.M.E.*
A-5	Less than 55% sand.....	>35	<Curve 3	>30	Curve 12 or Curve 13	>12
A-6	Seldom less than 30% clay.....	>35	Curve 4	Curve 5	>Curve 11	Between Curve 9 and Curve 10
A-7	Seldom less than 30% clay.....	>35	Between Curve 3 and Curve 4	Between Curve 5 and Curve 6	>Curve 11	Between Curve 9 and Curve 10
A-8	Not Significant...	>45	<Curve 3	Curve 6	>Curve 12	Between Curve 9 and Curve 10

Bureau of Public Roads System (*Continued*)

General Remarks	Structural Properties	Suggested Treatment for Stabilization
P.I. varies but is comparatively low. F.M.E. varies to indicate silts containing peat or elastic soils containing mica or diatoms.	Similar to A-4 Type but with high elastic qualities, appreciable rebound on removal of loads even when dry. Will not retain compacted density.	Treatment and drainage toward soil stabilization essential before paving is attempted. Compaction with heavy rollers apt to cause non-uniform rebound during paving construction. With non-plastic varieties, clay may be added to sometimes eliminate elasticity. Stage construction or bituminous material and cushion courses are advisable under a porous base course. With high ground water elevation and impractical drainage, asphaltic pavement is not recommended; a thick, heavily reinforced concrete type being more suitable.
A volumetric change greater than 17. For certain colloidal soils, the F.M.E. is less than Curve 11.	Practically non-elastic, sticky and colloidal clays without coarse material. In a wet, compressed state absorb water only if manipulated. They can be compacted to high density but possess high shrinkage and may be unsatisfactory because of excessive volume change.	Treatment and drainage toward subgrade stabilization essential before paving is attempted. Drainage necessary to intercept seepage when soil is in a permeable condition. Mechanical manipulation with a moderate amount of sprinkling is beneficial in fills. Fills should be built in dry weather, springs below piped away and coarse material added. Stage construction or a bituminous material treatment covered with a blotter layer of granular material may be beneficial. Application of hydrated lime prior to bitumen treatment tend to increase bitumen penetration. When the soil is homogeneous and drainage not feasible, ample load distribution should be provided by a thick macadam or rigid type pavement.
A low S.L. with high F.M.E. would indicate the presence of colloidal organic matter—higher S.L. indicate possibility of frost heave.	Elastic and capillary clays. May have considerable volume change.	Drain if possible to eliminate gravitational water. Mechanical manipulation and compaction will possibly prevent unequal expansion. Stage construction may prove beneficial and expansion may be reduced by bituminous material applications. When the soil is homogeneous and drainage not possible—method such as suggested under A-6 Type should be followed.
Waterlogging in the C.M. test indicates mucks with clay and colloid content; a high C.M.E. without waterlogging indicates very slightly decomposed peats.	Soft peats and mucks. High capillarity. Spongy and elastic and will settle under loads.	No beneficial treatment has been as yet devised. The capillary moisture may be reduced only when it is possible to get drains down more than 10′. A fill of coarse-grained soil should be built across these muck soils, which should be consolidated and when necessary displaced by explosive. Pavements should be of the rigid concrete type with ample beam strength.

NOTE: 'Curves" referred to are those developed as a result of work done by the United Stated Bureau of Public Roads. These curves and more complete data on soil properties may be found in "Engineering Properties of Soil", by C. A. Hogentogler, C.E.—McGraw-Hill—1937.

The curves are mathmatically developed as follows:

Curve 2 $P.I. = .25 \times L.L.$

Curve 3 $P.I. = \frac{L.L.-14}{1.60}$

Curve 4 $P.I. = \frac{L.L.-14}{1.07}$

Curve 5 $S.L. = 21-1.1\sqrt{L.L.\frac{L.L.-2}{800}}$

Curve 6 $S.L. = \frac{L.L.+86}{4.1}$

Curve 7 $S.L. = \frac{L.L.+26}{1.24}$

Curve 8 $C.M.E. = \frac{L.L.-14}{1.61}$

Curve 9 $C.M.E. = .72 \times L.L.$

Curve 10 $C.M.E = \frac{L.L.-14}{0.55}$

Curve 11 $F.M.E. = \sqrt{15.2\ (L.L.-16.3)+9}$

Curve 12 $F.M.E. = \frac{L.L-10}{1.03}$

Curve 13 $F.M.E. = \frac{L.L.-4}{0.85}$

(d) Grading of Soil Fractions Based on Particle Size

	U.S. Standard Screen Series		Particle Size			
			Millimeter		Inches	
	Passing	Held On	Maximum	Minimum	Maximum	Minimum
Gravel (Coarse Agg.)	.....	10 mesh	.....	2.000 mm.	.....	0.0787 ins.
Sand (Fine Agg.)	10 mesh	270 mesh	2.0 mm.	0.053 mm.	0.0787 ins.	0.0021 ins.
Coarse Sand	10 mesh	40 mesh	2.0 mm.	0.420 mm.	0.0787 ins.	0.0165 ins.
Fine Sand	40 mesh	270 mesh	0.42 mm.	0.053 mm.	0.0165 ins.	0.0021 ins.
Soil Mortar	10 mesh	.....	2.0 mm.	.....	0.0787 ins.	.....
Soil Fines	40 mesh	.....	0.42 mm.	.....	0.0165 ins.	.....
Silt	.....	.....	0.05 mm.	0.005 mm.	0.0021 ins.	0.00019 in.
Clay	.....	.....	0.005 mm.	.....	0.00019 ins.	.....
Colloids	.....	.....	0.001 mm.	.....	0.00004 ins.	.....

1″ = 25.4 mm. 1 mm. = 0.03937 ins. 1 micron = 0.001 mm.

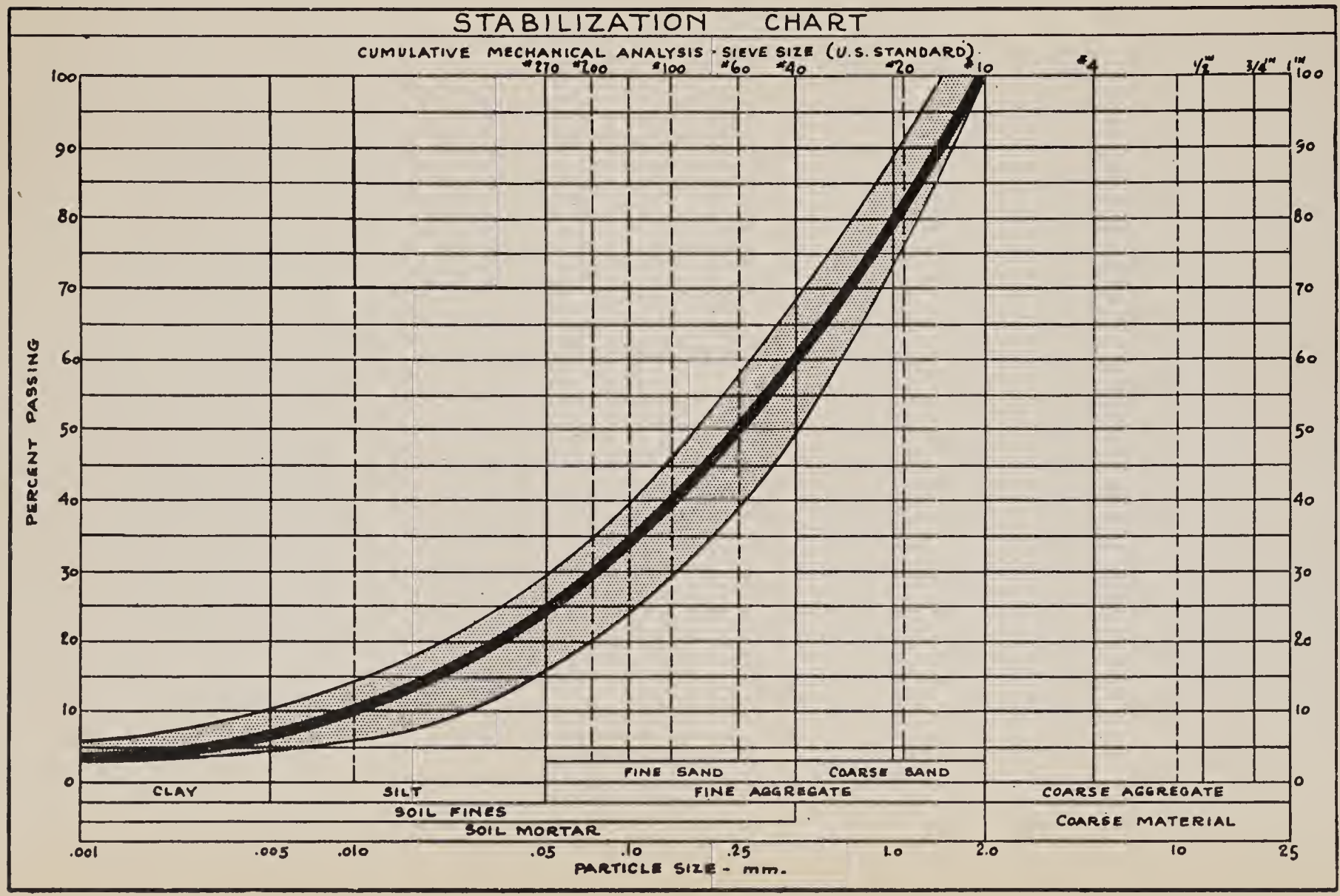
(e) CHARTS SHOWING IDEAL GRADING FOR MECHANICAL STABILIZATION SOIL MORTAR AND WEARING COURSE

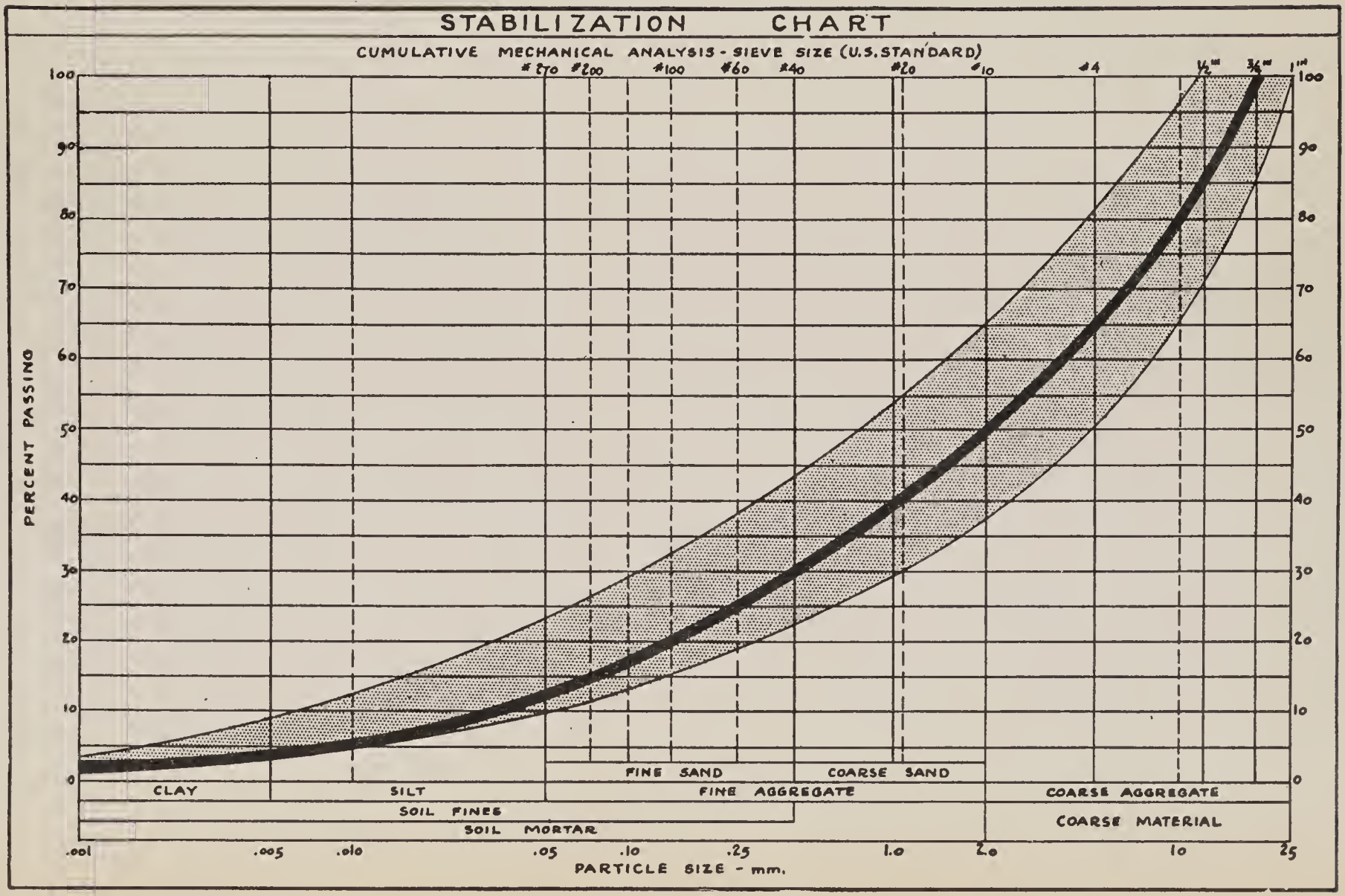
The following charts redrawn from ones published by The Bureau of Public Roads in PUBLIC ROADS, Vol. 12, No. 5, July, 1931, represent gradings of good soil mortar and an entire wearing course, including both coarse aggregate and soil mortar.

A mechanical or sieve analysis of the soil is made and the fraction of soil mortar passing the No. 10 sieve calculated to 100%. The resulting percentages are plotted against sieve openings or particle size on the chart and if the resulting curve falls within the shaded area, the gradation will be satisfactory. To use the second chart, representing the entire wearing course, a mechanical or sieve analysis is made and the fraction passing a 1″ sieve calculated to 100%. If the grading when plotted falls within the shaded area and if the curve has a distinct continuous slope, the material may be considered properly graded for a satisfactory wearing course.

The Plasticity Index of the binder in the ideal composition for wearing course is by this authority set at 8, with a permissible range of 6-14.

Other soil engineers are of the opinion that a P.I. of the binder of about 3 or 4 is desirable.


STABILIZATION CHART
CUMULATIVE MECHANICAL ANALYSIS - SIEVE SIZE (U.S. STANDARD)
#270 #200 #100 #60 #40 #20 #10 #4 1/2" 3/4" 1"
PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
CLAY
SILT
SOIL FINES
SOIL MORTAR
FINE SAND
COARSE SAND
FINE AGGREGATE
COARSE AGGREGATE
COARSE MATERIAL
.001
.005
.010
.05
.10
.25
1.0
2.0
10
25
PARTICLE SIZE - mm.


STABILIZATION CHART
CUMULATIVE MECHANICAL ANALYSIS - SIEVE SIZE (U.S. STANDARD)
#270 #200 #100 #60 #40 #20 #10 #4 ½" ¾" 1"
PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
CLAY
SILT
FINE SAND
COARSE SAND
FINE AGGREGATE
COARSE AGGREGATE
SOIL FINES
SOIL MORTAR
COARSE MATERIAL
.001 .005 .010 .05 .10 .25 1.0 2.0 10 25
PARTICLE SIZE - mm.

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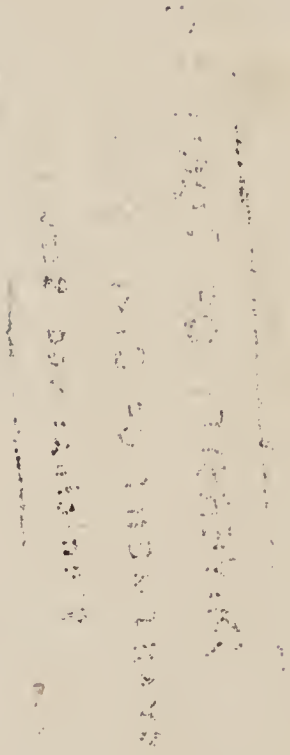

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